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The role of sugar cane in Brazil's history and economy

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THE ROLE OF SUGAR CANE IN BRAZIL'S HISTORY AND ECONOMY

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The role of sugar cane

in Brazil's history and economy

by

Plinio Mario Nastari

A Dissertation Submitted to the

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PREFACE

For a long time now, I have intended to bring together in one single study a host of information dealing with the influence of the cultivation of sugar cane in the history and economic development of Brazil. The appropriate time appeared to have come when I chose to develop an econometric model of the sugar and ethanol industries of Brazil to fulfill one of the requirements for the completion of my graduate studies. To develop this econometric model, I had to collect a considerable amount of data, bringing me in contact with the literature related to the production of sugar cane, sugar, and ethanol in Brazil. The opportunity to learn all about the evolution of the sugar cane culture was unveiled to me.

I enjoyed very much the endless process of digging out information, and checking for its accuracy and internal consistency. It is my wish to share with other individuals interested in the sugar cane industry what I have learned during this process of research.

This study is divided into three parts. Part I is concerned with the role of sugar cane in Brazil's history. It includes the Chapters II to VII. It starts with a background on the origin and dissemination of sugar cane throughout the world (Chapter II), and focuses on the evolution of the sugar cane culture in Brazil from 1500 to modern times. While Chapters III, IV and V deal with the evolution of sugar cane used for the production of sugar, Chapter VI deals with the production of ethanol from sugar cane. Although ethanol has been used as a fuel in Brazil since 1931, its importance in the energy matrix of Brazil has increased notably after the creation of the National Alcohol Program (Proálcool). Chapter VII presents a history of the creation of the Proálcool, providing insights on who participated in the decision process, and how these decisions were made.

Part II presents an econometric model of Brazil's sugar and ethanol industries. Chapter VIII presents a review of the modelling literature, and Chapter IX introduces the proposed theoretical model. Estimation of the model is presented in Chapter X. If the reader is only interested in the modelling part of this study, I suggest that he (she) skips Part I, with exception to Chapter VI which provides some background information about the production of ethanol in Brazil.

In Part III, the model estimated in Part II is utilized to carry on some policy analyses. Chapter XI reveals what should be the levels of a few government-controlled variables which would be in consistency with the established goals of ethanol production and consumption in Brazil. Chapter XII is concerned with the estimation of some income measures accrued by producers of sugar, producers of ethanol, and the government since the creation of the Proálcool. Chapter XIII summarizes the policy analyses, and provides a conclusion to the study.

I want to express my gratitude to all those persons who facilitated my access to the data utilized

in this study.

I specially acknowledge the help I received from Ermelindo Ruete de Oliveira, from the Usina Catanduva, during my field trip to Brazil in April 1983.

I am also personally thankful to Dr. Lamartine Navarro Jr., of the National Energy Commission; Antonio H. Pinazza, José (Zito) Fernandes, Ana Maria Gheller, Telmo Pimenta, and Ernesto Gatto, of the Sugar Cane Experiment Station of Araras (Planalsucar-IAA); and Júlio Maria Martins Borges and José Vianna of Copersucar, for all the information they have facilitated to me.

Most grateful thanks go to former President Ernesto Geisel, who kindly provided me with historical information about the creation of the Proálcool. My appreciation is also directed to Dr. Paulo Vieira Belotti and Dr. Getúlio Valverde de Lacerda for a host of historic information.

Many personal friends and relatives have contributed to the completion of this work when they sent me information, spontaneously or under request.

I specially thank my uncle Dr. Carlino Nastari, and my friends Dr. Ruth Lopes Ribeiro, João D. Biagi, Mr. David Wicker and Dr. Helenauro Soares Sampaio (both from National Distillers do Brasil Ltda.).

This work had the support of the Coordenadoria de Aperfeiçoamento do Pessoal de Nível Superior. Profa. Cristina Argenton Colonelli, and Profa. Silvia Bahia before her, have always maintained a high degree of professionalism.

Dr. Earl O. Heady has been a remarkable major professor. He has given me timely and important advice and support. I am indebted to the members of my committee for their suggestions: Dr. Roy Hickman, Dr. William Meyers, Dr. Dennis Starleaf, and Dr. James Stephenson. I am specially thankful to Drs. Stephenson and Meyers for their interferences. Thanks to Dr. Meyers for accepting Dr. Heady's request to review the early drafts of this study, while Dr. Heady was consulting abroad.

Thanks also to Joan Burg from the Media Resources Center at Iowa State University for preparing the illustrations in time.

I am grateful to Mrs. LaDena Bishop for her comments concerning the format and presentation of the results.

I deeply appreciate the incentive that I have received from uncle Carlino Nastari, uncle Olavo Trindade, and my friend Dr. Ruth Lopes Ribeiro.

To my parents I express my heartful thanks for their love, and for having always stressed the value of education.

I dedicate this study to my wife, Rute, who did not mind to spend our honeymoon collecting the data used in this study, and in recognition of all the strength and support she has given to me.

The fruit derived from labor is really the sweetest of pleasures.

Plinio Mario Nastari

Ames, Iowa
October, 1983

CHAPTER I.

INTRODUCTION

Antecedents

Brazil's economic history and social structure have been linked to the culture of sugar cane in many aspects. Sugar cane provided the economic base for the Portuguese occupation of Brazil upon its discovery in 1500. It influenced considerably the ethnic composition of Brazil, via the traffic of slaves from Africa which were brought to work in the sugar cane plantations and mills. From the sugar industry emerged Brazil's colonial aristocracy, and the first sign of the nation's stratification in economic classes.

During the colonial period (1500 to 1822), the wealth generated from the trade of sugar was enormous. In relative terms, the value of sugar exports during the entire colonial period is twice the value of all the gold and diamonds mined in Brazil during the same period.[1]

Profits from the production and trade of sugar remained largely in the hands of the Portuguese tax collectors, other foreign merchants--mostly the Dutch--and the owners of sugar plantations and mills. However, because the economic interests of the first two groups resided outside of Brazil, and because of the lavish life style of the proprietors of colonial sugar mills, only a small fraction of the sugar wealth was reinvested in Brazil towards the development of other economic activities.

Although the volume of sugar exports continued to expand throughout the 1800s, the total value of sugar exports decreased due to lower international prices.[2]

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[1]The value of sugar exports from 1526 to 1822 is estimated at £300,000,000 (pounds of 1936), whereas the value of gold and diamonds is estimated at £170,000,000. Brazil was the world's largest producer of gold and diamonds during the 1700s. See Chapter V for details.

[2]Between 1826 and 1830, annual sugar exports averaged 54,796 metric tons valued at £1,369,600, whereas

Decreases in the price of sugar were a result of aggressive competition among producers, and the loss of sugar's specialty value among consumers.

Starting in 1835, sugar lost to coffee the position of Brazil's largest source of of export revenues, and for nearly 120 years the sugar industry struggled to modernize its production lines, in a process that left untouched thousands of small-scale mills.

During the 1900s, in spite of the large degree of uncertainty inflicted upon net returns by very unstable international sugar prices, Brazil's production of sugar continued to grow, now leveraged by the more efficient sugar factories that emerged from the modernization process.[1]

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between 1896 and 1900 annual sugar exports averaged 113,908 metric tons, or £1,288,800 (nominal values unadjusted for inflation). Refer to Table 7 in Chapter V.

[1] Today, most of Brazil's sugar production--approximately 9 million metric tons in 1982--comes from large factories that utilize modern vacuum pans and centrifuges in the production process. Production of non-centrifugal sugar is estimated to be around 300,000 metric tons per year.

These new, large sugar factories started producing also large quantities of residual molasses, a by-product of the sugar production process. Residual molasses were in turn used as the main input in the production of ethanol. As one might expect, production of ethanol from molasses picked up in almost every sugar producing country, as the supply of molasses tended to exceed demand.

Indeed, the wide availability of ethanol made its use as transportation fuel as old as the automobile. At the turn of the century, a Berlin brewery powered a truck with ethanol, and in fact all the original automakers experimented with ethanol as fuel for the internal combustion engine. Ethanol competed with petroleum products on the basis of availability and price.

Ethanol from molasses became commonplace in Brazil, being sold as "motor alcohol" in various states of Brazil often outside of sugar mills.

For a long time, ethanol from molasses constituted an important supplementary source of income to the sugar industry, which supported its use as a fuel and as an input to the chemical industry.

Recently, the most important development in Brazil's sugar industry is the production of ethanol directly from sugar cane. This initiative could provide a viable alternative for the use of sugar cane when the export price of sugar is not as attractive, or rewarding.

The interest on increased ethanol production was sparkled by the 1973 rise in the price of petroleum, which inflicted heavy losses to Brazil's oil-dependent economy. A National Alcohol Program was established in 1975 to coordinate and monitor efforts towards the production of ethanol as a substitute to petroleum derivatives. A measure of the impact of this program is given by the evolution of ethanol production since its creation. In 1976, the total production of ethanol (hydrous and anhydrous) was 642 million litres, whereas in 1982 it achieved 5,300 million litres. In 1980, the proportion of anhydrous ethanol mixed to gasoline was 14.14 percent, and in 1982 the fleet of vehicles using straight (hydrous) ethanol outnumbered 625,000--or 7 percent of the total fleet.

Nature of the Problem

The sugar and ethanol industries of Brazil are interelated in a complex manner.

Before the establishment of the National Alcohol Program in 1975, the volume of ethanol derived from biomass produced in Brazil was relatively small, as it derived mostly from residual molasses. Today, the picture gets much more complicated as the quantity supplied of ethanol is the sum of the ethanol produced from molasses, and of the ethanol produced directly from sugar cane.

Moreover, for any given year, there is a total quantity supplied of <u>sugar cane</u> which is decided upon one-and-a-half year in advance. Thus, for any given year the supply of <u>sugar cane</u> is given, and the production of <u>sugar</u> and <u>ethanol</u> will compete for the use of sugar cane unless there is enough of it for both industries. Since the government determines the price of <u>sugar cane</u> received by producers (which likely affects the quantity supplied of sugar cane in the future), it is important to have a price policy for sugar cane which is consistent with the target production levels of sugar and ethanol.

Indeed, the sugar and ethanol industries are among the most regulated of Brazil. The government sets the prices paid to ethanol and sugar producers, the cost of labor, and the proportion of ethanol to be added to gasoline, among other things. Because these variables can influence the demand and supply of sugar and ethanol (hydrous and anhydrous), it is crucial that they are set at levels that are consistent with predetermined national objectives. This study is an effort to at least partly address this issue, through the formulation of a simultaneous econometric model of the sugar and ethanol industries of Brazil. It will also focus on the quantification of the value of net returns accrued by sugar and ethanol producers, as well as the net revenue of the government with the National Alcohol Program.

Because sugar cane has been very important throughout Brazil's economic history, a brief review of of the history of sugar cane in Brazil is also included.

Objectives

The three major objectives of this study are as follows:

1) Review the history and evolution of the sugar cane culture in Brazil, from 1500 to modern times.[1]

2) Develop a model that adequately explains the economic relationships of supply and demand of sugar, hydrous ethanol, and anhydrous ethanol in Brazil overtime.[2]

3) Determine the level of some policy variables that would be consistent with the publicly advertised national objectives of ethanol production.

4) Determine the value of net returns accrued by

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[1]This section is presented in Part I.

[2]This section is presented in Part II.

sugar and ethanol producers, and the net revenue of the government with the National Alcohol Program.[1]

[1]The last two sections are presented in Part III.

PART I.

THE EVOLUTION OF THE SUGAR CANE CULTURE FROM 1500 TO MODERN TIMES

CHAPTER II.

A BRIEF HISTORY OF THE SUGAR CANE

Introduction

The sugar cane is a perennial tropical grass belonging to the family Gramineae, which also includes wheat, oats, corn, sorghum, and johnson grass. Modern sugar cane varieties derive from interbreeding of two or more of the six species of the genus *Saccharum*:[1] *Saccharum barberi* Jeswiet, *Saccharum officinarum* L., *Saccharum robustum* Brandes and Jeswiet ex Grassl, *Saccharum sanguinarum* Grassl, *Saccharum sinense* Roxburgh, and *Saccharum spontaneum* L.[2]

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[1] George P. Meade and James C. P. Chen, *Cane Sugar Handbook* (New York: John Wiley and Sons, 1977), p. 3.

[2] The designation *barberi* honors Dr. C. A. Barber; *officinarum* means "of the apothecaries' shops;" *robustum* stands for robust; *sanguinarum* means "blood colored;" *sinense* denotes "Chinese cane;" and *spontaneum* is for "wild cane."

The sugar cane plant has been known to mankind from the earliest times, and is referred to in historical records going back into the remote days of old civilizations which flourished long before the Christian era. However, the actual extraction of sugar from sugar cane was developed only during the early sixth century. Until then, sugar cane was used for chewing and its juice for drinking.

Origin

There is some controversy over the exact origin of the most primitive species of sugar cane, but there is general agreement among scientists that this grass originated in southern Asia.

The modern accepted view[1] is that the *Saccharum* genus evolved in the India-Burma area, where the three species *S. spontaneum*, *S. barberi*, and *S. sinense* are indigenous. As the canes spread to other areas,

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[1]Meade and Chen, *Cane Sugar Handbook*, p. 3.

S. robustum appeared in southeast Indonesia, where its more fibrous varieties were used for construction, and its sweeter and juicier forms were used for chewing.[1] Between 15,000 and 8,000 B.C., S. robustum evolved into S. officinarum in New Guinea,[2] which is thought to be the authentic geographical centre of all "noble," or pure, canes.[3]

Early cultivation of sugar cane was dominated by a natural hybrid between S. barberi and S. officinarum, which remained unnamed for centuries. During the eighteenth century this hybrid variety was named "creole"[4] to distinguish it from the noble varieties of S.

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[1]F. S. Earle, Sugar cane and its culture (New York: John Wiley and Sons, 1928), p. 4; and Noël Deerr, Cane Sugar (London: Norman Rodger, 1921), p. 13.

[2]Ernst Artschwager and E. W. Brandes, Sugar cane (Saccharum officinarum L.): origin, classification, characteristics, and description of representative clones, Agriculture Handbook Nº 122 (Washington, D.C.: Government Printing Office, 1958), pp. 9-18.

[3]E. W. Brandes, Proceedings of the International Society of Sugar Cane Technologists, Ninth Congress, 1956, p. 731.

[4]When other varieties were introduced it came to be known as native cane, caña del pais, caña de la tierra, or more often as "creole cane."

officinarum brought from New Guinea by the sea captains.[1]

The first reference to sugar cane is undated, and comes out of an ancient piece of Indian literature called Vajasaneji-Samhita, written during the Mantra period, which lasted from 1,000 to 800 B.C. In the translation made by Griffith[2] of this book there is a portion devoted to the ritual of horse sacrifice which reads "I gratify fresh grass with his teeth," and for "fresh grass" some other comentators have written "sugar cane."[3]

The earliest dated record of the presence of sugar, and by inference of sugar cane, in western India comes from Admiral Nearchus, who was sent down the Indus

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[1]Captain Bougainville, the first French navigator to sail round the world, has the credit for having been the first to bring a cane directly from its home. He arrived in Mauritius on November 8, 1768, in the frigate Boudeuse, and left there a cane which afterwards became known as Bourbon, or Otaheite. Account of later similar efforts by Captains Bligh, Laforey, Edwards, and Cook can be found in Noël Deerr, The History of Sugar, vol. 1 (London: Chapman and Hall, 1949), pp. 19-24.

[2]The Text of the White Yajurveda, Vedas Yajurveda, Vajasaneji-Samhita, XXV, I, trans. Ralph T. H. Griffith (Benares: E. J. Lazarus and Company, 1899).

[3]Deerr, The History of Sugar, vol. 1, p. 40.

river by Alexander the Great to explore the Indian seas in 325 B.C.[1] He describes it as a "reed which yields honey without the help of bees . . . (and yields) an intoxicating drink even though the plant does not bear fruit."[2]

References to the word "sweet cane" can also be found in several parts of the Old Testament, which apparently indicate that it was an article coming from a far country. Two of these passages read:

> Thou has bought me no sweet cane with money, neither hast thou filled me with the fat of thy sacrifices.[3]

> To what purpose cometh there to me incense from Sheba, and the sweet cane from a far country? Your burnt offerings are not acceptable, nor your sacrifices sweet unto me.[4]

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[1]E. O. von Lippman, Geschichte des Zuckers (Berlin: Julius Springer, 1929), cited by Andrew Van Hook, Sugar: its production, technology, and uses (New York: Ronald Press, 1949), p. 127.

[2]William Reed, The History of Sugar (London: Longmans, Green, 1866), p. 1.

[3]Isaiah 43:24.

[4]Jeremiah 6:20.

Knowledge of the existence of sugar cane by the Greeks and the Romans is attested by many writers. Paulus Egineta refers to it as "Indian salt," likening it to salt, except for its sweet taste. Theophrastus mentions it as "another honey which comes from bamboos."

Dioscorides was the first writer to use the word <u>Saccharum</u>[1] in 35 B.C., indicating its origin in the following passage:

> There is a sort of concreted honey which is called sugar, found upon canes in India and Arabia Felix; it is in consistence like salt, and is brittle between teeth.[2]

Pliny, the Elder, says:

> Arabia produces sugar, but that of India is more renowned. It is a kind of honey collected from bamboos. It is white as gum, breaks easily under the teeth, and is very useful in medicine.[3]

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[1]Later in this chapter we present a quick analysis of the origin of the word "sugar."

[2]Reed, <u>The History of Sugar</u>, p. 2.

[3]William C. Stubbs, <u>Sugar Cane: a treatise on the history, botany, and agriculture of sugar cane, and the chemistry and manufacture of its juices into sugar, and other products</u> (New Orleans: Sugar Experiment Station, Louisiana State University, 1897), p. 3.

An example of the early appreciation devoted to sugar comes from Seneca, who observes that "there is found among the Indians a honey contained in the reed; this honey is produced either by the dew of heaven or by the sweet and thick sap of the reed."[1]

These references to sugar cane constitute today's documented evidence that the genus <u>Saccharum</u> indeed originated in southern Asia, most probably in India, and was a novelty item to civilizations which emerged west of the Indian subcontinent.

Dissemination

The sweet and honeylike nature of sugar cane became known outside of India in very early times, through the reports and writings of Nearchus, Pliny, Seneca, Paulus Egineta, Theophrastus, Herodotus, Hippocrates,[2]

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[1]Stubbs, <u>Sugar Cane</u>, p. 3.

[2]Hippocrates (460?-370? B.C.), the Greek physician, recommended the medicinal use of sugar, stating that "the sweet is the healthiest," and that "honey with wine is most suitable for man."

Dioscorides, and Galen.[1] However, consumption and cultivation of sugar cane began to spread beyond southern Asia only after the art of evaporating sugar cane juice to a solid product was developed around A.D. 500.[2] It is believed that the culture of sugar cane spread from India along the shores of the Persian gulf, until it reached the rich alluvial soil of the rivers Tigris and Euphrates, south of Bagdad.[3] From there, sugar cane spread to the coast of the Caspian sea, and reached Egypt in the year 710.[4]

The Arabs' natural taste for sweets stimulated the consumption of sugar as a confection and beverage, encouraging the cultivation of sugar cane in every land they occupied. As a result of the Arab conquests, sugar

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[1]Galen (A.D. 129-200) exulted the virtues of "the stuff called sakcharon from India and Araby."

[2]G. L. Spencer and P. M. Meade, <u>A Handbook for Cane Sugar Manufacturers and Chemists</u> (New York: John Wiley and Sons, 1889).

[3]W. R. Aykroyd, <u>The Story of Sugar</u> (Chicago: Quadrangle, 1967), p. 13.

[4]Meade and Chen, <u>Cane Sugar Handbook</u>, p. 30.

cane reached Spain by 714,[1] and Sicily by 950.[2]

During the entire Middle Ages period, sugar was a very expensive commodity, often chosen for kingly gifts and kept in the inventories of many monarchs among other treasures.

The Italian cities of Florence and Venice flourished with the enormous wealth generated by the trade of sugar and other spices brought from India. The use of cloves, black pepper, and cinnamon was very important to the medieval cuisine which relied heavily upon the consumption of meat. The meat was stored for long periods through the use of salt and oil infusions. Venice was specially important for its supremacy as a sugar refining center, since the sugar of those days was a highly impure and dark product.

The dominance of Florence and Venice over this trade lasted until 1453 [3] when the land route to India

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[1]Reed, The History of Sugar, p. 3.

[2]Meade and Chen, Cane Sugar Handbook, p. 30.

[3]Van Hook, Sugar, p. 136.

was interrupted by the fall of Constantinopla to the Ottoman turks. However, there is evidence to indicate a reduction in the profits of Italian merchants over the trade of sugar as early as 1420. Around this date, the sugar cane culture was introduced to Madeira from Spain,[1] and from there to the Canary Islands, Azores, Cape Verde, and West Africa in 1480.[2]

The competition of the Portuguese sugar lowered market prices in Europe substantially. In 1440, a pound of sugar cost 0.553 grams of gold.[3] In 1470, this price had fallen to one third of a gram of gold and, by 1501, to one fifteenth of a gram.[4]

Although not much can be said about the relative price of sugar, compared to other products constituting the common consumption basket of those times, it is clear

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[1] G. C. Stevenson, Genetics and Breeding of Sugar Cane (London: Longmans, 1965), p. 40.

[2] Van Hook, Sugar, p. 130.

[3] Which is equivalent to $8.3 at a price of gold of $450 per troy-ounce.

[4] Roberto C. Simonsen, História Econômica do Brasil: 1500-1820, vol. 1 (São Paulo: Companhia Editora Nacional, 1944), p. 145.

that a substantial fall in the price of sugar resulted from the expansion of the Portuguese production. Lower prices affected revenues accrued by the Portuguese treasury to such an extent that, in 1498, El-Rei Dom Manuel determined the state's intervention over production, limiting annual exports out of Madeira to a maximum of 1,800 metric tons.[1]

From the Canary Islands, sugar cane was brought to Hispaniola [2] by Columbus during his second trip to the American continent in 1493.[3] The first attempts to grow sugar cane in Hispaniola failed completely, but success was achieved in 1506 in the western part of the island now known as the Republic of Haiti, under the direction of Nicolás de Ovandro. By 1520, there were twenty sugar mills operating on the island, and by 1550 this number had increased to forty.[4]

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[1]Simonsen, História Econômica do Brasil, p. 146.

[2]The island which today encompasses Haiti and the Dominican Republic.

[3]A. C. Barnes, The Sugar Cane (New York: John Wiley and Sons, 1974), p. 2.

[4]Simonsen, História Econômica do Brasil, p. 146.

From Hispaniola, sugar cane was taken to Puerto Rico in 1515, and to Mexico in 1522,[1] although exports from Mexico to Europe did not start until 1553.[2] The greater attention devoted to the extraction of silver and gold in Mexico and Peru, and the exodus from the Caribbean islands to these areas, cooled down initiatives to produce sugar in the West Indies until the middle of the seventeenth century, when sugar prices rose considerably due to increases in demand.

Sugar cane was introduced in Brazil upon its discovery in 1500. However, shipment of sugar to Portugal apparently did not start until 1526.

Pizarro took sugar cane with him to Peru in 1529 and encouraged its cultivation there. The first export of sugar from the Philippines occurred in 1565.

Sugar cane does not seem to have been established in Argentina before 1620. Members of the clergy (Jesuits)

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[1]Cortez encouraged the industry in Mexico, and promoted a factory at San Andres Tuxtla in 1522.

[2]Simonsen, História Econômica do Brasil, p. 146.

introduced it to Louisiana in 1751. In 1798, sugar cane was brought into Cuba by Arango, from Saint Croix.[1] In the eighteenth century, sugar cane was introduced to Mauritius, Reunion, Japan, and Hawaii, and to Australia, Fiji, and South Africa during the 1800s.[2]

Figure 1 illustrates the flow of dispersion of sugar throughout the world.

Semantics

Saccharum, a latin word, is the denomination given to all sugar producing canes. The origin of the word Saccharum can be traced out to the ancient Sanskrit word karkara, which means sand or gravel. This association suggests that sugar in its early forms was ground into powder. In the Pakrit language which succeeded Sanskrit,

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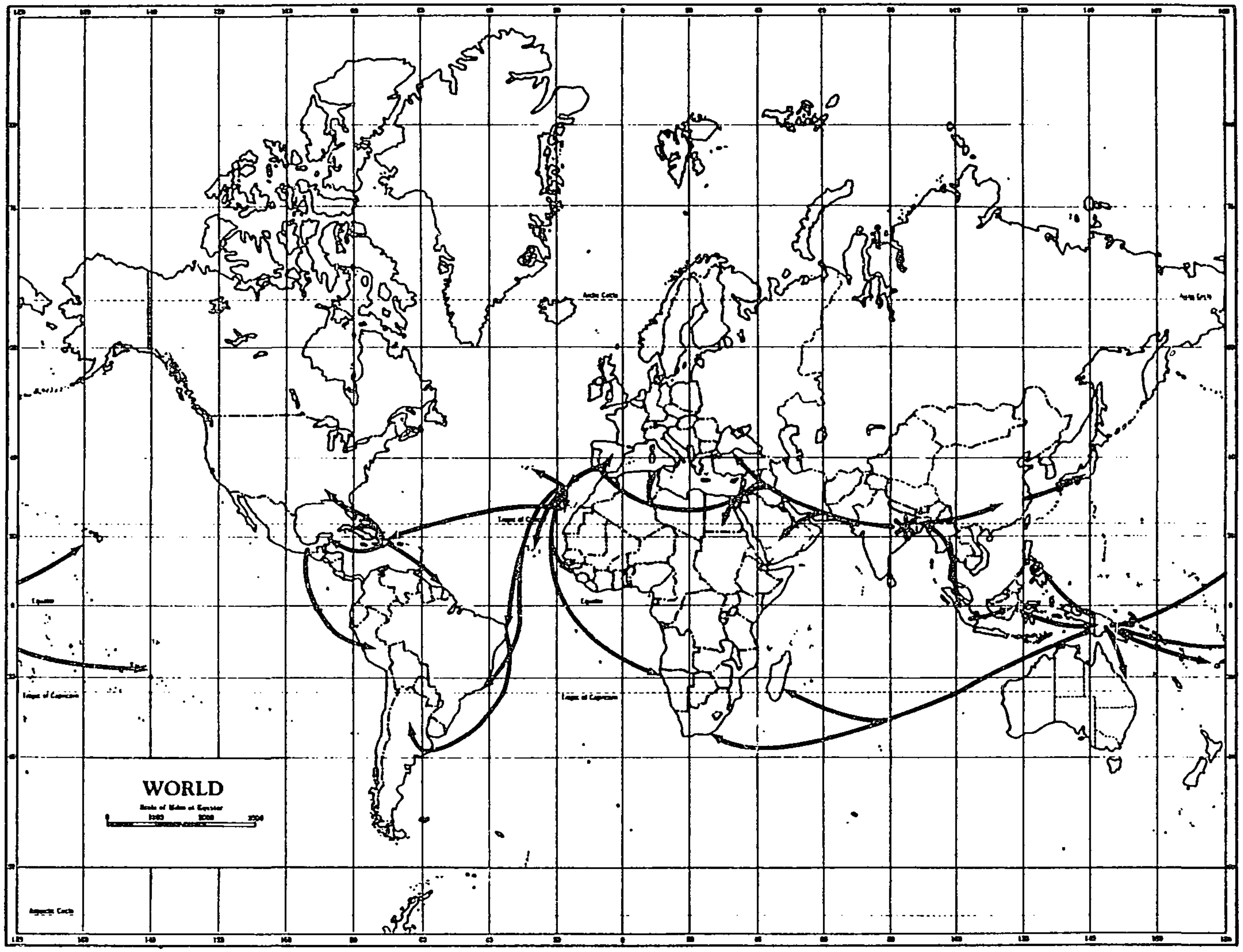
[1] J. G. Cantero, Los Ingenios: collecion de vistas de los principales ingenios en la isla de Cuba (Havana, 1857), cited in Deerr, The History of Sugar, vol. 1, p. 20.

[2] Meade and Chen, Cane Sugar Handbook, p. 30; for exact dates consult Deerr, The History of Sugar, vol. 1, p. 20.

Figure 1. Route of dispersion of sugar cane throughout the world


WORLD

karkara became *sakkara*,[1] from which the latin *Saccharum* was derived.

The Arabic form of *sakkara* is *sukkur*, from which the Portuguese word *açúcar*, the Spanish *azúcar*, the French *sucre*, and the Italian *zúcchero* derived. *Sukkur* is also believed to be the parent word for the German *zucker*, the Dutch *suiker*, the Swedish *socker*, the Hungarian *czukor*, and the English *sugar*, which appeared in the English literature as early as the thirteenth century.[2]

Current Sugar Cane Production

Sugar cane holds a leading place in the vast expansion in the production of agricultural crops that occurred since the sixteenth century, and most notably during the 1900s.[3] The tremendous increase in the

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[1] Aykroyd, *The Story of Sugar*, p. 7.

[2] E. O. von Lippmann, *Geschichte des Zuckers* (Berlin: Julius Springer, 1929), cited in Van Hook, *Sugar*, p. 127.

[3] Barnes, *The Sugar Cane*, p. 57.

consumption of sugar is closely associated to the widespread use of specialty beverages such as tea, coffee, cocoa, and more recently soft drinks.[1]

During the 30 years from 1950 to 1980, the total area harvested of sugar cane in the world has tripled, from 4.4 to 13.2 million hectares.[2] Among the major crops this record is surpassed only by the cultures of soybeans, and sunflower seed. However, in relative terms, sugar cane occupied in 1980 only one fourth of the area occupied by soybeans. Similar comparisons with other crops are even more surprising, as one realizes that the area harvested of wheat was 18 times larger than the area of sugar cane, the area of rice was 11 times larger, and the area of corn was 10 times larger.

Indeed, the total area harvested of sugar cane in 1950 appears to be really small, if one realizes that an unseemingly crop such as chick-peas occupied an area 2.4

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[1]Other industrial uses for sugar and its molasses include: alcoholic fermentation, flavoring of tobacco, ink thickener, and sizing for textiles.

[2]Refer to Table 1 for the exact figures.

TABLE 1

WORLD'S HARVESTED AREA OF SELECTED CROPS IN 1950 AND 1980

Crop	1950 (000 ha)	1980 (000 ha)	Percentage Change
Sugar Cane . . .	4,388	13,249	202
Cereals, total .	470,000	726,266	55
Wheat	129,300	236,883	83
Rice	94,400	143,534	52
Corn	83,000	128,764	55
Millet and sorghum . . .	74,500	88,260	18
Barley	38,600	78,588	104
Oats	35,900	24,935	-31
Roots and tubers, total	. . .	48,217	. . .
Potatoes . . .	12,500	17,978	44
Sweet potatoes	7,300	12,026	65
Cassava	5,342	13,777	158
Pulses, total .	36,800	62,444	70
Dry beans . . .	16,000	23,823	49
Chick-peas . .	10,500	9,489	-10
Peas	5,500	7,030	28
Lentils	1,170	1,768	51

TABLE 1-Continued

Crop	1950 (000 ha)	1980 (000 ha)	Percentage Change
Soybeans	15,100	51,816	243
Groundnuts in shell	11,600	18,673	61
Sunflower seed .	2,970	12,208	311
Cottonseed . . .	25,800	32,975	28
Coffee	. . .	9,847	. . .
Cocoa	. . .	4,584	. . .
Grapes	8,400	9,997	19
World's arable & permanent crop area	1,300,000	1,452,215	12

SOURCE: United Nations, Food and Agriculture Organization, Production Yearbook (Rome: FAO, 1953, and 1981).

times as large in the same year. Thus, although sugar cane is one of the leading sources of energy in human nutrition, it occupies only a small fraction (0.9 percent) of the world's arable land, because of its high tonnage per planted area.

Production

The production of sugar cane by countries is presented in Table 2. The five-year averages show that the most significant increases in the production of sugar cane from the mid 1930s to the early 1980s have occurred in Brazil and India. During this period, Brazil's production increased from 17 million to 154 million metric tons, and the production of India grew from 67 million to 150 million metric tons in 1981.

Most other major producers of sugar cane show increases in production, although not as large in absolute terms.

TABLE 2

AVERAGE YEARLY WORLD SUGAR CANE

PRODUCTION (in Thousand Metric Tons)

Region or Country	1981	1976-1980	1961-1965	1948-1952	1934-1938
World	775,285	736,563	470,931	266,400	225,600
Africa	64,687	58,637	30,790	14,000	10,500
Egypt	9,076	8,790	4,755	2,185	1,469
South Africa .	16,720	18,031	9,454	4,789	3,757
North & Central America . . .	171,625	164,860	125,923	86,000	54,200
Cuba	67,000	63,397	42,385	45,920	26,176
Dominican Rep.	11,600	10,456	7,326	4,388	
Mexico	35,461	33,672	25,178	10,419	3,775
United States	27,076	24,579	20,091	5,759	5,171
South America .	219,249	195,425	113,700	60,500	35,000
Argentina . .	15,260	15,604	11,431	7,596	5,934

Brazil	153,858	127,528	65,577	32,837	16,968
Colombia . . .	25,900	23,160	13,846	8,406	
Asia	290,357	291,491	184,843	89,900	110,900
China	33,000	40,435	24,705	7,115	
India	150,522	151,145	106,563	53,730	67,500
Indonesia . . .	17,560	15,288	9,225	5,621	
Pakistan . . .	32,359	27,994	15,849	10,120	
Philippines . .	20,450	21,060	13,159	7,700	8,228
Thailand . . .	18,600	19,050	704	990	261
Oceania	28,983	25,793	15,259	15,200	14,800
Australia . . .	25,160	22,687	12,936	6,686	5,206

SOURCE: United Nations, Food and Agriculture Organization, Production Yearbook (Rome: FAO, 1956, 1973, 1975, 1978, and 1981).

CHAPTER III.

THE HISTORY OF SUGAR CANE IN BRAZIL FROM 1500 TO 1630

It is believed that Pedro Capico brought the first sugar cane plants to Brazil,[1] although the exact date is uncertain. The earliest evidence of the presence of sugar cane in the land is given by the records of the Lisbon Custom House, which show the collection of duties on sugar coming from Brazil in 1526.[2]

Motivation

The introduction of sugar cane to Brazil marks the beginning of its economic occupation by the Portuguese. It was less motivated by the need of expanding

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[1] Simonsen, História Econômica do Brasil, p. 147.

[2] Waetjens, Weltwirtschaftliches Archief (Jena, 1921), p. 176, cited by Deerr, The History of Sugar, vol. 1, p. 102; and Francisco Adolfo Varnhagen, História Geral do Brasil: antes de sua separação e independência de Portugal (São Paulo: Itatiaia, 1981).

sugar production, than it was for the political pressure exerted on Portugal and Spain by other European nations.

During the fifteenth century, Portugal and Spain had achieved a singular position among other emerging European monarchies, mainly because of their great advances in overseas navigation.[1] From mere medieval states, Portugal and Spain evolved into sea powers in the commerce with the East Indies.

By the late 1400s, sailing ships departed towards the East Indies, in search of spices and silk, but not so much for sugar anymore. By that time, the Portuguese had already established a thriving sugar production system in the Atlantic islands of Madeira, Azores, and Cape Verde, which helped disrupt the Italian merchants' hegemony over the commefe of sugar in Europe.[2] Indeed, the production of sugar in the islands had been sufficiently large to

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[1] The successful development of navigation skills among the Portuguese is linked to the establishment of the famous School of Sagres, by the Infante Dom Henrique (1394-1460), known as "the Navigator."

[2] After the fall of Constantinopla, in 1453, Italian merchants bought sugar from the Arabs in Egypt for more expensive prices.

send sugar prices plummeting down in European markets.[1] The risks associated with long-distance transportation deemed freight costs so high that the only profitable overseas commerce involved manufactured products and oriental spices.

Therefore, cane was not brought to Brazil to expand the production of sugar. The reason which motivated Portugal to do so was the prevailing principle among European nations that the Spanish and the Portuguese should be entitled only to those tracts of land which they had effectively occupied. Threats, mostly from France, in the form of expeditions with populating purposes towards the northern coast of Brazil[2] urged some sort of economic occupation of the land by the Portugueses. It became clear that the Portuguese territories would be lost if some colonization effort was not implemented.

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[1]Refer to Chapter II for information about the price of sugar during this period.

[2]Celso Furtado, Formação Econômica do Brasil (São Paulo: Companhia Editora Nacional, 1976), p. 6.

The Colonization System

Although the date of April 22, 1500 has been for a long time the official date for the arrival of the first European explorers to the coast of Brazil, today it is widely accepted that on January 26, 1500 Vicente Yañez Pinzón, a pilot of Columbus during his discovery trip to America, had already reached Brazil. He landed at latitude 8° South, and christened the area Cape Consolation.[1]

Just a couple of months later, on March 8, 1500, thirteen ships carrying 1,200 men sailed from the Tagus river in Portugal under the command of a nobleman called Pedro Álvares Cabral. His stated mission was to follow the route to India discovered by Vasco da Gama in 1497-1499, and to bring back a full load of merchandises. However, Cabral was driven westwards by contrary winds when trying to double the Cape of Good Hope, in Africa,

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[1]Robert Southey, History of Brazil (New York: Burt Franklin, 1971), p. 3.

and landed at a site he called Porto Seguro,[1] located at latitude 17° South, on Good Friday, April 22, 1500. He took possession of Brazil for the Portuguese Crown on Easter Monday.

Although Pinzón had reached Brazil ahead of Cabral, Spain never pushed its claim because the newly discovered land fell within the Portuguese sphere as delineated by the Tordesilhas Treaty. At Tordesilhas, in 1494, representatives of the monarchs of Portugal and Spain agreed to divide the world. An imaginary line, running pole to pole 370 leagues (approximately 2,284 kilometers) west of the Cape Verde islands, gave to Portugal everything discovered at 180 degrees east, and to Spain everything at 180 degrees west.

In subsequent years, various exploration trips were made alongside the coast encountering great abundance of brazilwood, a tree yielding a red pigment used in the dyeing of textiles. Because of the economic importance of this native resource, the territory's name which had

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[1]Meaning "secure port."

already been changed from Ilha de Vera Cruz to Terra de Santa Cruz[1] was again modified to Terra do Brasil, and the name Brasil[2] quickly gained popular acceptance. That name first appeared on a map in 1511, when Jerônimo Marini so identified the land mass of easthern South America on his globe.[3]

To rapidly occupy the territory of Brazil, and construct fortifications on its wide coastal front, would have required monetary resources not available in the Portuguese coffers. Instead, the Crown instituted the donatárias, or captaincies, whereby the new territory was divided into charters which were granted to wealthy Portuguese merchants and noblemen against the responsibility of occupation of the land. These hereditary

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[1] Meaning "Island of the True Cross," and "Land of the Holy Cross," respectively.

[2] In Portuguese, the word and official name of the country is spelled with the letter s. Throughout this study we will use the English spelling: Brazil.

[3] E. Bradford Burns, A History of Brazil (New York: Columbia University Press, 1970), p. 21.

captaincies extended over 150 miles of coast, together with its hinterland, and in them the donatário had absolute powers.

Martim Affonso de Souza, a distinguished navigator and one of the first donatários, explored the whole coast of Brazil, discovering the harbour of Rio de Janeiro on the New Year's day of 1531.[1] In 1532, he brought in sugar cane plants from Madeira, and established a sugar mill in 1533 at São Vicente, distant seven miles from the port town of Santos in the state of São Paulo, marking the real beginning of sugar exploration in Brazil. At first this factory was called "Engenho do Senhor Governador," and later on "Engenho dos Armadores," due to the association of Pero Lopes de Sousa e Pero Lopes da Silveira. The sugar mill was eventually sold to two Flemish merchants, Erasmus Esquert and Julius Visnats, and became known as the "Engenho de São Jorge dos Erasmos."[2]

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[1] Afterwards he became Viceroy of the Indies.

[2] Deerr, The History of Sugar, vol. 1, pp. 103-104.

By the fourth decade of the sixteenth century the price of sugar in London had increased from its lowest level of one fifteenth of a gram of gold in 1501 to 0.305 grams of gold per pound.[1] The rise in the price of sugar was a reflection of the flourishment of the Commercial Revolution, which is characterized by a general rise in prices, and increasing consumption of all itens of trade. The rapid development of trade was fueled by the great influx of wealth, in terms of precious metals, coming from the Spanish conquests in America. Sugar not only followed the general trend, but became the main article of international trade.

To encourage the establishment of new sugar mills in its American colony, Portugal granted many incentives to whoever installed these factories, such as tax exemptions for ten years, and distribution of privileges given only to the noble.

With the production of sugar from Madeira, Azores,

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[1]Simonsen, História Econômica do Brasil, p. 143.

and Cape Verde, Portugal had dominated the world trade of sugar since the middle of the fifteenth century. Beginning in 1560, the expansion of the Brazilian industry became so vigorous that by the end of the century measures were taken to protect the production of Madeira, which was threatened by the risk of price decreases due to the influx of Brazilian sugar, in the form of a 20 percent tax on Brazilian exports.[1] Indeed, by 1590 there were already 108 sugar mills in Brazil,[2] of which 36 in the state of Bahia, and 66 in the state of Pernambuco, with the later number increasing to 120 by 1600.[3]

At any rate, by 1600 the industry of sugar was already decadent in Madeira, and the cultivation of grapes for wine had become the leading economic activity. Sugar mills did not disappear completely, and in 1649 the

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[1] K. W. Volz, Beiträge zur kulturgeschichte, der einfluss dess menschen auf die verbreitung, der hausthiere und der kulturpflangen (Leipsig: B. G. Teubner, 1852), p. 318.

[2] Van Hook, Sugar, p. 135.

[3] Ibid., p. 141.

Council of Funchal, in Madeira, offered premia to anyone who would repair the old factories or build new ones.[1]

In 1560, the production of sugar in Brazil inaugurates an era which lasted until 1760, during which Brazil becomes the biggest supplier of sugar to Europe. Table 3 shows the quantity of sugar exported from Brazil during the colonial period.

Slavery as a Source of Labor

The first sugar mills extracted the cane juice utilizing man-operated presses. This old system was substituted in Brazil by larger factories, operated by water or animal force, which had an annual production capacity of 45 metric tons, or more. During the colonial period, the average production capacity of a sugar mill was 150 metric tons of sugar per year,[2] which exceeded in much the more primitive installations at Madeira.

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[1]Volz, <u>Beiträge zur kulturgeschichte</u>, p. 696.

[2]Simonsen, <u>História Econômica do Brasil</u>, p. 149.

TABLE 3

QUANTITY AND PRICE OF RAW SUGAR EXPORTED FROM BRAZIL DURING THE COLONIAL PERIOD (UNTIL 1820)

Year or Period	Quantity Exported (in Metric Tons)	London Price of Raw Sugar (in Grams of Gold per Metric Ton)
1560-1570	2,654	746
1580	5,161	749[a]
1600	17,695	935
1610	10,838	963
1617	14,746	. . .
1630	22,118	812
1640	26,542	993
1650	30,966	890
1670	29,491	558
1700	25,805	. . .
1710	23,593	536
1760	36,864	473
1776	22,118	476
1796	22,708	339[a]
1806	22,118	220[a]
1812	6,783	235[a]
1820	69,304	261

SOURCE: Simonsen, História Econômica do Brasil, pp. 172-173.

[a]Figures refer to the price of raw sugar in Lisbon.

The typical sugar mill in Brazil was an intricate enterprise because it not only required the production and industrialization of cane, but also of food for its large contingent of slaves, and of pasture for the animals used for transportation and industrial works. Simonsen quotes the following passage from Porto Seguro and Rodolfo Garcia:

> The sugar mill was a real settlement, not only making use of many men, but also of the necessary cultivated areas of cane, of forests for wood, of pastures, and of food. Indeed, within the headquarters, the living quarters, the slaves' quarters, and the nursery, one could count about one hundred men working on 1,200 tarefas[1] (1,292 acres) of cane planted area, besides the pastures, fences, utensils, iron, copper, cars, and animals.[2]

Working at the sugar mills required a lot of physical strength and endurance, which coupled with the hot and humid climate of the shores of Brazil made the

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[1]<u>Tarefa</u> is a measure of area containing 900 square <u>braças</u>, and is equal to 4,356 square meters, or 0.4356 hectares.

[2]Simonsen, <u>História Econômica do Brasil</u>, p. 149.

task very strenuous for the European settlers. These circumstances induced the search for labor within the native indians and the blacks, which became essential elements for the development of the culture of sugar cane in Brazil.

Although many attempts were made to enslave native indians for the sugar works, these efforts proved not to be fruitful because of their strong resistance to captivity and work in the heavier duties.

The experience of the Portuguese in Madeira on the use of enslaved labor from nearby African colonies of Portugal served as testing grounds for the use of black slaves in the Brazilian sugar mills. It is believed that the first negroes directly brought in from Africa arrived in Brazil in 1538.[1] In 1585, out of a total population of 57,000 there were approximately 14,000 black slaves, a majority of them settled in the state of Pernambuco. After this date, many additional crossings of

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[1]Burns, A History of Brazil, p. 38.

the Atlantic were made to bring the productive enslaved laborers.

As a matter of fact, a direct route was not the only one followed to bring slaves to Brazil. A triangular route was very common, practiced mainly by Portuguese and Dutch ships, carrying European goods to the African colonies, African slaves to Brazil, and Brazilian sugar to Europe.

It is estimated that over the span of three centuries some 3.5 million slaves survived the Atlantic crossing to Brazil. By centuries, the estimated numbers are: sixteenth century, 100,000; seventeenth, 600,000; eighteenth, 1,300,000; nineteenth, 1,600,000.

The Interbreeding of Races

The Portuguese settlers adapted very quickly to the new environment found in Brazil, since it was very similar to those already found during their trips to

Africa and the East Indies.

The contingence of European women was very small during the first two centuries of Brazil's colonial history, thus the Indian women fell prey, and submitted themselves, to the desires of the Portuguese settlers. As a result, there appeared an interbred race called the <u>mameluco</u>, or <u>caboclo</u>, which quickly spread over the country, and was as adapted to the local environment as it was to European customs.

Similarly, with the introduction of the Africans, many Portuguese men again attested to the Iberian sexual prowess by establishing another race, called the <u>mulato</u>.

The contribution of the Africans to Brazil's evolution goes much beyond the service of strong and reliable labor. The Africans helped explore and conquer the new land, and many times to defend it from other colonial powers as well. They are responsible for the introduction of many aspects of today's Brazilian culture, which include religion, food, and folklore. African women served as babysitters to the children, and as companions to the wifes of the <u>senhores de engenho</u> (meaning "lords of the sugar mills").

Indeed, the interbreeding of races was so significant that in 1803 the population of the city of São Salvador in the state of Bahia was composed of 30,000 white (including caboclos), 30,000 mulatos, and 40,000 blacks.

Burns describes the homogeneization of races in this way:

> The three groups, Indian, European, and African lived and mixed together with, all factors considered, a minimum of friction. In the process three continents fused sexually, socially, linguistically, and culturally to form a nation much more homogeneous than any other of comparable size. A hybrid civilization emerged and so did a new type of man, the Brazilian, the compounded product of extraordinarily diverse elements. It would not be an exaggeration to affirm that this new "race" conquered the new land.[1]

The cultivation of sugar cane, introduced to Brazil during this first phase of the colonial occupation, is important for it provides the reaison d'être for the

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[1]Ibid.

close association between the Indians, Europeans, and Africans, which intermingled around the communities formed for the industrialization of sugar.

Reasons for the Success of the Sugar Cane Culture in Brazil

An array of positive factors contributed to the success of the sugar cane culture in Brazil, an enterprise which also marks the first large scale agricultural venture ever attempted by any European nation in one of its colonies.

It is hard to believe that the large scale production of sugar in Brazil would have succeeded without the relative technical advances attained by the Portuguese in Madeira and other Atlantic islands. The expertise to produce sugar can be considered to be the first requirement for the installation of the sugar cane culture in Brazil.

The second fundamental element for the success of Brazil's sugar enterprise is the contribution given by the Dutch in expanding the existent, and creating new, markets for sugar, during the second half of the sixteenth century. Holland was the only nation with sufficient commercial organization in Europe to create a market of great dimensions for a new product such as sugar.

Thirdly, the Dutch contributed not only commercially, but also financially. A substantial amount of capital was required for the installation of the sugar industry, and most of it came from Holland, which financed the marketing of the product, as well as the installation of sugar mills.[1]

Finally, the problem of availability of labor was solved by the acquaintance that the Portuguese had already developed with the slave markets in Africa. Slave labor turned out to be the only cheap alternative capable of supporting the installation of a profitable sugar cane enterprise. The work conditions in the colony were such that only paying higher wages than those paid in Europe would the Portuguese have attracted interested workers to

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[1]Furtado, Formação Econômica do Brasil, p. 11.

Brazil. The option of paying for the labor with land seems to not have represented an attractive idea since the land was of little value without large capital inversions.

In summary, the introduction of sugar cane in Brazil met with success because the technical expertise was available to the Portuguese, the markets were developed and financial resources provided by the Dutch, and the availability of cheap labor was assured by the traffic of slaves.[1] There is no doubt that the inability of any one of these conditions to be met would have doomed the success of the sugar cane exploration in the colony of Brazil.

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[1]The reliance on slave labor came about because of the failure by the Portuguese to utilize native Indians in sedentary agricultural activities, and because of the inability of the European settlers to satisfy the demand for labor. The sugar industry would have hardly succeeded without the importation of millions of Africans in bondage. However, in addition to its inhumanism, slavery had at least two long-range serious disadvantages for free Brazilians: slaves were not active consumers, therefore the domestic market remained quite small; and the slaves presence depressed wages, which inhibited the development of a free small proletariat in most areas.

CHAPTER IV.

CAUSES AND CONSEQUENCES OF THE DUTCH OCCUPATION OF BRAZIL (1630 TO 1654)

In 1602, the Dutch East India Company was formed to carry raw sugars, mainly from Java, to the refineries in Amsterdam and Antwerp. From these two commercial centers, the Dutch distributed refined sugar to most of northern Europe. However, by no measure were the Dutch newcomers to the trade of sugar.

The Dutch had been associated to the Portuguese in the distribution and sale of sugar coming from Brazil since the third quarter of the sixteenth century. During some periods, Dutch vessels carried over half of the trade between Brazil and Portugal.[1] For a long time, the Dutch and the Portuguese had gotten along well together, but their friendly relationship ended when Philip II of

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[1]Burns, <u>A History of Brazil</u>, p. 45.

Spain ascended the Portuguese throne.

Antecedents

In 1580, the last of the Aviz kings of Portugal died, and for 60 years the Spanish monarchs ruled Spain and Portugal jointly. During this period, the Spanish rulers treated the Portuguese colonies with carelessness, devoting most of their attention to their own gold and silver producing colonies. At the same time, the Dutch were fighting a war for their independence from the Spanish Habsburgs, and found the sworn animosity of the Castilians, to which Philip II belonged.

Before 1591, ships of any flag could trade in Brazilian ports, so long as they cleared from a Portuguese port first.[1] In 1585, and again in 1590, 1596,

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[1] The metropolitan authorities imposed this obligation in order to guarantee tax collections on colonial products, and to favor home merchants. For Brazil, this policy had clear disadvantages: the exporters did not receive the higher prices paid in the consumer markets, the importers had to pay transshipment costs through Portugal, and many entrepreneurs were prevented from

and 1599, Philip II ordered the seizure of all Dutch vessels in Portuguese ports, and the imprisonment of their crews.[1]

The Dutch rightly regarded liberty as the best thing. Next to liberty they valued profit. As a result of the actions taken by Philip II, the Dutch sought retaliation.

By establishing the East India Company in 1602, the Dutch aimed at reaching the sugar producing areas of India and Java, as alternatives to the uncertain trade route to Brazil. They were very successful in this venture, and after strengthening their finances for two decades the Dutch West India Company was formed, in 1621, with full powers to encourage colonization and commerce through conquest. Its chief objective was to invade Brazil, with the pleaded motive that by so doing a pure religion would thus be introduced into America.[2] Reli-

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establishing local industries by the metropolitan commercial interests.

[1]Southey, History of Brazil, p. 476.

[2]Ibid., pp. 477-478.

gious morals, as usual, were perverted to serve the purposes of avarice and ambition.

Indeed, the attack on Brazil would not have materialized if it was not for the large profits it would have yielded. One of the leaders of the Dutch West India Company, Jan Andries Moorbeek, prepared a profit and loss statement of the trade of sugar from Brazil for 1620, which is reproduced in Table 4. This accounting statement serves as a measure of how attractive to the Dutch was the capture of Brazil, and of how lucrative was the trade of sugar in those times.

The Dutch Occupation

In 1624, the Dutch West India Company made its first attempt to place a foothold in Brazil by attacking the colony's capital of São Salvador, in the captaincy of Bahia. This advance marked the start of an undecisive war that lasted for two years.

In 1630, the Dutch once more set sail towards Brazil, now directing their forces to the city of Olinda,

TABLE 4
PROFIT AND LOSS STATEMENT OF THE TRADE
OF SUGAR FROM BRAZIL IN 1620
PREPARED BY JAN ANDRIES MOORBEEK

Item	Gulden	£
20,000 chests of *blancos* at 8 *groots* per lb.	2,000,000	183,333
20,000 chests of *muscovados* at 4 *groots* per lb. . . .	1,000,000	91,667
20,000 chests of *panelas* at 2 *groots* per lb.	500,000	45,833
Total	3,500,000	320,833
Freight and cost to Amsterdam at 12 *gulden* per chest	720,000	66,000
Grand Total	4,220,000	386,833
Selling price in Amsterdam of *blancos*, 18 *groots* . .	4,500,000	412,500
Selling price in Amsterdam of *muscovados*, 12 *groots* .	3,000,000	275,000
Selling price in Amsterdam of *panelas*, 8 *groots* . . .	2,000,000	183,333
Total	9,500,000	870,333
Cost	4,220,000	368,833
Profit	5,280,000	484,000

Source: J. J. Reesse, *De suikerhandel van Amsterdam, van het begin der 17de eeurv tot 1813, een bijdrage tot de handelsgeschiedenis des vaderlands, hoofdzakelijk uit de archieven verzameld en samengesteld* (Haarlem: J. L. E. I. Kleynenberg, 1908), p. 187, cited by Deerr, *The History of Sugar*, vol. 1, p. 105.

in the captaincy of Pernambuco. The fleet consisted of more than fifty ships under the general command of Hendrick Loucq, with Pieter Adriaensz as Admiral, and Colonel Diderick Van Wardenburgh as Commander of the Troops.[1] The whole expedition consisted of 7,000 men, of which half were soldiers. The target city of Olinda at the time of the capture had only 2,000 inhabitants, besides 130 members of the clergy, and did not resist the outnumbering attack.

So started the Dutch occupation of the north-eastern coast of Brazil, which would include the captaincies of Pernambuco, Itamaracá, Paraíba, Sergipe, and Rio Grande do Norte.

Maurice of Nassau

Many sugar cane plantations and sugar mills were destroyed during the Dutch campaign, which was conducted

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[1] Ibid., p. 513.

with little foresight. In 1635, the number of sugar mills left capable of operation was reduced to 120, of which 67 were in Pernambuco, and still many of them were partly wrecked.

This policy was not in the best interest of the Dutch West India Company, which was seeking rapid profits. Reorganization of the sugar production scheme was only attempted after the arrival of Count Joan Maurice of Nassau, sent by the company in 1637 with full powers as General-Governor.

Count Maurice proved to be a great statesman. Under his administration, the forced sales of sugar mills as a source of revenue were canceled, the fugitives recalled, a moratorium on old debts was declared, state loans were advanced for the reconstruction of damaged mills and machinery, and supplies for use in sugar mills were admitted free of duty. Moreover, the export duties on sugar were reduced, "as sugar in its present depressed market can no longer support these,"[1] according to Count

[1] Deerr, The History of Sugar, vol. 1, p. 106.

Maurice's reasoning, which, nevertheless is not supported by the documented evidence on prices.[1]

One of his most innovative enactments was the establishment of a meteorological station, where records of rainfall were taken by the Dutch scientist Macgrav, who was in his staff. These represent the first official meteorological records anywhere, as the earliest known in Europe are those made in 1653, by order of Ferdinand II of Tuscany.[2] These were only a few of the many measures Maurice of Nassau took to lay the foundations of an empire that was not to be.

Although Maurice's reforms heralded great prosperity in the colony, they did not appeal to the Dutch West India Company, which was more interested in keeping its profits, than in permanent occupation, and large capital investments. In 1644, Count Maurice was recalled,

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[1] In reality, sugar prices were not depressed, reaching an all time high in the history of colonial Brazil of 993 grams of gold per metric ton of raw sugar, or 0.450 grams per pound, in 1640, at the London market.

[2] Deerr, The History of Sugar, vol. 1, p. 106.

and shortly after his departure the company demanded the repayment of all outstanding loans.[1]

The period of the Dutch occupation under Maurice of Nassau is marked by large and successive increases in the amount of sugar exported from Brazil. This occurred in response to the massive investments that were made during his administration. The figures in Table 3 indicate that, in 1617, before the Dutch occupation, less than 15,000 metric tons were exported, whereas in 1650 that figure had more than doubled to nearly 31,000 metric tons. This mark is not to be surpassed for more than 100 years. The expansion of production was motivated in great part by the high price of sugar in Europe, around the middle of the 1600s. It is also noteworthy that 1650 marks the peak year in export revenues from sugar for the entire colonial period. In that year, total revenue from the export of sugar reached the equivalent of 27,560 kilograms of gold (refer to Table 3, in Chapter II).

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[1]This decision was reversed afterwards, because of the inability of proprietors to repay the loans.

A policy of repression substituted the incentives introduced by Maurice of Nassau, and upon Portugal's independence from Spain, in 1640, a national feeling arose in Brazil against the Dutch. The war of liberation was headed by a wealthy planter from Madeira called João Francisco Vieyra. Meanwhile, the newly formed House of Bragança, which ascended to the Portuguese throne, quickly allied itself with England. With the outbreak of war with England, as a consequence of the Navigation Acts, the Dutch were unable to send reinforcements to Brazil.

In 1654, Pernambuco fell to Vieyra, and the Dutch left their endeavours in Brazil. A final peace treaty between Portugal and Holland was signed in 1662, whereby the Dutch West India Company received an indemnity of 8,000,000 gulden (the equivalent of £733,333), to be spread over sixteen years. In 1674, the company seized to exist, with a loss upon liquidation of 28,000,000 gulden (£2,566,667).[1]

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[1]Deerr, The History of Sugar, vol. 1, p. 107.

Consequences of the Expulsion

In 1654, the Dutch administration was expelled, and with it also the Dutch settlers, of whom there were approximately 20,000. Along with them went the Portuguese jews living in Brazil, who provided a host of support to the Dutch during their occupation, and against whom the influence of the Jesuits was directed.

This short-sighted policy greatly damaged the sugar industry in Brazil, because of the evacuation of capital owned by the expelled Dutch settlers, and jews. These potential investors migrated to the West Indies and Guianas, where they were instrumental in reviving the ailing sugar industry which was introduced in the early decades of the sixteenth century. There, they established a thriving sugar industry which soon became a powerful competitor with that of Brazil. This time, the Dutch gave up their ambitions of profit through conquest, and preferred to work in cooperation with other colonial powers, namely Britain, France, and Denmark.

The settlers took along with them not only large sums of capital, accumulated during the prosperous years of the Dutch occupation of Brazil, but also the knowledge and expertise of sugar manufacturing they acquired there. The Dutch cooperation was welcomed by the French and the British colonies in the Caribbean sea, because of the great difficulties they were encountering from the depressed prices of their traditional cultures: tobacco, and cotton.

As Furtado[1] points out, less than a decade after the Dutch were expelled from Brazil, the Antilles housed a sugar industry of considerable proportions, with new equipment, and with a more favorable geographical location. The sugar interests controlled large extensions of land, and owned large-scale sugar mills. There was a rapid decrease in the population of settlers, brought initially to the area by the British and the French in

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[1]Celso Furtado, Formação Econômica do Brasil, pp. 26-28.

their early colonization efforts, while the number of African slaves increased vertically.

Harlow provides an account of the changes in the population of Barbados, after the reintroduction of sugar cane:

> Already, in 1667, this substitution of the negro slave for the white servant had reached an advanced stage. In that year Major Scott stated that after examining all the Barbarian records he found that since 1643 no less than 12,000 'good men' had left the island for other plantations, and that the number of landowners had decreased from 11,200 small-holders in 1645 to 745 owners of large estates in 1667; while during the same period the negroes had increased from 5,680 to 82,023. Finally he summed up the situation by saying that in 1667 the island was not half so strong, and forty times as rich as in the year' 1645.[1]

The flourishment of the sugar industry in the West Indies drove most of the original European settlers to the British colonies located in the northern part of the continent. This migration was instrumental in

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[1]V. T. Harlow, A History of Barbados: 1625-1685 (Oxford: Clarendon Press, 1926), p. 310.

transforming the later colonies in autosufficient and economically viable units, as they became food suppliers to the export-oriented sugar producing islands of the Caribbean sea.

Thus, it is not an exaggeration to say that the expulsion of the Dutch from Brazil, which during their occupation acquired the most current and developed technology of sugar production of those times, would lead to the disruption of Brazil's hegemony in the production of sugar, and would influence the colonization, and social structure of the European colonies in the West Indies, and North America.

CHAPTER V.

THE EVOLUTION OF BRAZIL'S SUGAR CANE CULTURE FROM COLONIAL TO MODERN TIMES

After the mid seventeenth century, the Dutch, the British, and the French colonies in the West Indies squeezed Brazilian sugar out of its traditional markets[1] by virtue of their greater proximity to Europe, dominance of marketing channels, and greater availability of capital. However, it would be erroneous to think that after 1650 Brazil's sugar enterprise collapsed.[2]

The Prominence of Sugar in Brazil's Exports During the Colonial Period

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[1]Complete figures of the production of sugar in the British, Dutch, French, and Danish West Indies can be found in Deerr, The History of Sugar, vol. 1, pp. 158-245 passim.

[2]It took more than a century for the Brazilian sugar to lose its hegemony in the European markets.

For 150 years until 1800, the European sugar markets continued to expand vigorously, absorbing the increasing production of sugar from the West Indies. During the same period, exports of sugar from Brazil tended to a stagnant position, fluctuating between 20,000 and 35,000 metric tons per year.

Although the year of peak in the quantity of sugar exported from Brazil is achieved in 1760--with 36,864 metric tons of raw sugar--the value of these exports, measured in grams of gold, is equal to only sixty percent of the value of sugar exports in 1650 (see Table 3 in Chapter III). Indeed, the price of sugar in 1760 was half of the price in 1650; and by 1812 it had halved again.[1] This gradual decline in the price of sugar in Europe is a consequence of its more widespread consumption,[2] and the subsequent loss of its value as a

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[1]The price of sugar is being measured in terms of grams of gold per unit of weight. Refer to Table 3.

[2]As an example, the per capita consumption of sugar in Britain rose from four pounds per year in 1700 to eighteen pounds per year in 1800. Refer to Noël Deerr, <u>The History of Sugar</u>, vol. 2 (London: Chapman and Hall, 1950).

specialty commodity.

Even though the volume of sugar exports from Brazil declined between 1650 and 1800, in no occasion during this period it lost its position as the most important item in Brazil's export list. Simonsen estimates the total value of sugar exports from Brazil during the entire colonial period (1500-1822) at £300,000,000 (in 1937 prices). This value amounts to more than half of the total value of all commodities exported from Brazil, and almost twice the value of Brazil's second largest export group--gold and diamonds--during the 322 years considered (see Table 5). Indeed, sugar is going to be outranked by another export product, coffee, only in 1830.

Composition of Brazil's Exports During the Nineteenth Century

During the 1800s, sugar gradually loses its prominence as an export crop, responding to only six percent of Brazil's total exports by the end of the

TABLE 5

TOTAL VALUE OF EXPORTS FROM BRAZIL, BY COMMODITIES DURING THE COLONIAL PERIOD (1500 TO 1822)

Commodity	Total Value of Exports (in £)[a]
Sugar	300,000,000
Gold and Diamonds	170,000,000
Hides	15,000,000
Brazilwood, and other timber	15,000,000
Tobacco	12,000,000
Cotton	12,000,000
Rice	4,500,000
Coffee	4,000,000
Cocoa beans, and other spices	3,500,000
Total	536,000,000

SOURCE: Roberto C. Simonsen, História Econômica do Brasil: 1500-1820, vol. 2 (São Paulo: Companhia Editora Nacional, 1944), p. 220.

[a]Pounds of 1937.

century (see Table 6). Coffee becomes the new "king" of international trade. Even the value of natural rubber exports dwarfed those of sugar at the beginning of the twentieth century.

Although the relative figures show a dramatic shift in the ranking of export items during the 1800s, the volume of sugar exports increased significantly. The figures in Table 7 indicate that the volume of sugar exports in the 1880s reached a level 500 percent above the apogee of the colonial period. Such performance leaves no doubt about the continuing expansion of sugar production throughout the nineteenth century.

Technical Progress in the Production of Sugar

The first quarter of the nineteenth century marks the beginning of the Industrial Revolution in Europe and North America. This movement left Brazil untouched, and its sugar industry remained in the conditions it had

TABLE 6

VALUE OF SELECTED BRAZILIAN EXPORT PRODUCTS IN RELATION TO TOTAL EXPORTS

(in percent)

Years	Sugar	Gold and Diamonds	Cotton	Coffee	Hides	To-bacco	Cocoa	Natural Rubber
1500-1822	56.0	31.7	2.2	0.7	2.8	2.2	0.7	. . .
1821-1830	30.1	. . .	20.6	18.4	13.6	2.5	0.5	0.1
1831-1840	24.0	. . .	10.8	43.8	7.9	1.9	0.6	0.3
1841-1850	26.7	. . .	7.5	41.4	8.5	1.8	1.0	0.4
1851-1860	21.2	. . .	7.5	48.8	7.2	2.6	1.0	2.3
1861-1870	12.3	. . .	18.3	45.4	6.0	3.0	0.9	3.1
1871-1880	11.8	. . .	9.5	56.6	5.6	3.4	1.2	5.5
1881-1890	9.9	. . .	4.2	61.5	3.2	. . .	. . .	8.0
1891-1900	6.0	. . .	2.4	64.5	. . .	. . .	1.5	15.8
1901-1910	1.2	. . .	2.1	51.3	. . .	. . .	2.8	27.9

SOURCES: Simonsen, História Econômica do Brasil, vol. 2, p. 220; Nelson W. Sodré, História da Burguesia Brasileira (Rio de Janeiro: Civilização Brasileira, 1967); Mircea Buescu and Vicente Tapajós, História do Desenvolvimento Econômico do Brasil (Rio de Janeiro: Casa do Livro, 1969), p. 28; Virgilio Noya Pinto, "Balanço das Transformações Econômicas no Século XIX," in Carlos Guilherme Mota, ed., Brasil em Perspectiva (São Paulo: Difusão Européia, 1968), p. 139.

TABLE 7
BRAZILIAN SUGAR AND COFFEE EXPORTS (1821-1910)

Years	Sugar			Coffee		
	Annual Tons	Average £ Value[a]	Percent Total Export Value	Annual Tons	Average £ Value[a]	Percent Total Export Value
1821-1825	41,174	983,600	23.2	12,480	739,600	17.6
1826-1830	54,796	1,369,600	37.8	25,680	698,200	19.7
1831-1835	66,716	1,091,500	23.5	46,980	2,001,500	40.7
1836-1840	79,010	1,320,800	24.3	69,900	2,428,000	46.0
1841-1845	87,979	1,264,600	21.6	85,320	2,058,200	42.0
1846-1850	112,830	1,650,600	27.5	120,120	2,472,800	40.9
1851-1855	127,874	1,882,200	21.5	150,840	4,113,000	48.6
1856-1860	98,864	2,445,400	21.2	164,160	5,635,000	48.7
1861-1865	113,551	1,943,600	14.0	153,300	6,863,400	49.3
1866-1870	109,001	1,717,800	10.7	192,840	6,737,400	42.5
1871-1875	169,337	2,353,400	11.8	216,120	10,487,800	52.0
1876-1880	167,761	2,354,600	11.8	219,900	12,103,000	60.7

1881-1885	238,074	2,646,000	13.7	311,760	11,359,000	58.8
1886-1890	147,274	1,537,200	7.0	307,800	14,380,800	64.5
1891-1895	153,333	2,182,800	7.2	361,092	20,914,000	69.2
1896-1900	113,908	1,288,800	4.7	532,800	16,669,400	60.4
1901-1905	78,284	637,000	1.6	740,280	20,952,200	53.0
1906-1910	51,338	479,600	0.8	826,908	27,877,000	50.5

SOURCES: Affonso de Escragnole Taunay, Pequena História do Café no Brasil (1727-1937) (Rio de Janeiro: Departamento Nacional do Café, 1945), pp. 547-549; Peter L. Eisenberg, The Sugar Industry in Pernambuco (Berkeley: University of California Press, 1974), pp. 9-10.

[a]Nominal value unadjusted for inflation.

during the seventeenth century.

In 1813, there were 458 sugar mills in the state of São Paulo, with a total production of 1,800 tons. As late as 1833, there were 603 mills in the state of Bahia producing approximately 16,000 tons per year, or an average of 27 tons per factory.[1] The production of sugar in such a small scale suggests that most of the sugar mills employed a primitive technology for the time, based on the use of bullocks or, at the most, water power.

Nevertheless, it is noteworthy that the first steam engine arrived in Brazil in 1815, being among the earliest to work on a sugar mill.[2] The machinery was built by Boulton and Watt (who also sent one to Rio de Janeiro in 1818), and was installed in the estate of "Mata-Paciência" owned by Donna Marianna, eldest daughter of the Baron of Campos. Although this achieve-

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[1] Deerr, The History of Sugar, vol. 1, p. 111.

[2] Gilberto Freyre, The Masters and The Slaves (New York: Knopf, 1946), p. 382.

ment stans among the first in the world towards the modernization of the sugar industry, many other records[1] indicate a conspicuous lack of progress until 1877.

In 1875, the government arranged a scheme for the concession of loans to be used in the construction of modern central factories. As a result, by 1877 the "Central Quissama" was inaugurated in the state of Rio de Janeiro. In 1878 the "Barcellos Central" was started, being quickly followed by the "Central Nossa Senhora das Dores," and the "Central Cupim" in 1882, all in the state of Rio de Janeiro.

The inauguration of these central factories mark the beginning of the technological transformation of the Brazilian sugar industry. Yet, for many decades to come, the large factories would coexist side-by-side with thousands of small, primitive sugar mills. In 1935, there

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[1]See Henri Raffard, Indústria Saccharífera no Brasil (Rio de Janeiro: Lombaertz, 1882).

were still 22,261 small sugar mills in Brazil, with annual outputs varying from 3 to 300 metric tons per year. On the other hand, the number of central factories in that same year was 268, of which 80 were in Sergipe, 62 in Pernambuco, 32 in São Paulo, 27 in Rio de Janeiro, 23 in Alagoas, 21 in Minas Gerais, and 16 in Bahia.

The Expanding Production of Sugar

During the nineteenth century, most European countries initiated the extraction of sugar from sugar beets. Although the production of sugar beets has never been sufficiently large to satisfy the increasing local demand, it contributed to the world overproduction of sugar. International agreements were signed in an attempt to control the world's production, the first one in 1864, and the second--The Brussels Convention--in 1902.[1]

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[1] For details read Roy A. Ballinger, A History of Sugar Marketing, Economic Research Service, Agricultural Economics Report Nº 197 (Washington, D.C.: Government Printing Office, 1971), pp. 14-15.

The Brussels Convention is generally regarded as the first effective international agreement regulating the trade of sugar. However, it lost its meaning at the outbreak of World War I, as the European sugar beet fields were destroyed, and many rural workers enlisted into the fight. Until 1921, the international market of sugar suffered from the lack of sufficient supplies, and many sugar cane producing countries took this opportunity to expand sugar exports.

At the start of World War I in 1914, Brazil exported 31,860 metric tons of sugar (531,000 bags of 60 kilograms). By 1918, this volume had risen to 115,636 metric tons, achieving 252,112 metric tons in 1921.[1] However, as the Great War came to an end agricultural production picked up again in Europe, and Brazil's sugar exports dropped to 34,466 metric tons in 1923. A new period of depressed prices of sugar would last until the early 1930s.

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[1]Hugo P. Oliveira, "40 Anos de I.A.A.--Antes e Durante," Brasil Açucareiro 81(June 1973):9-12.

In 1931, a new international agreement--The Chadborn Agreement--is established whereby nine countries (Cuba, Java, Germany, Poland, Hungary, Belgium, Peru, Czechoslovakia, and Yugoslavia) adhere to export fixed quotas for five years.[1] Countries adhering to the agreement accounted for nearly fifty percent of the world's sugar production in 1931. By 1934, they had only twenty five percent,[2] and the Chadborn Agreement resulted in by losses to its signataries.

In 1933, the Institute of Sugar and Alcohol (IAA--Instituto do Açúcar e do Álcool) is created in Brazil with the specific task of coordinating domestic production and exports of sugar from Brazil. As its denomination suggests, the IAA is also made responsible for the coordination of all the efforts to produce alcohol from sugar cane. According to IAA's first president, Leonardo Truda, "the defense of sugar . . . is seen to be indissolubly linked

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[1]Exclusive of Cuban exports to the United States.

[2]Ballinger, A History of Sugar Marketing, p. 36.

to the large-scale production of alcohol as fuel (as) the stable and definitive solution to the sugar problem in Brazil."[1]

Throughout its existence, the IAA is very successful in promoting the modernization of Brazil's sugar industry, and the establishment of a unified trade policy. After 1936, the production of centrifugal sugar[2] in Brazil grows at an exponential rate, reaching approximately 8.5 million metric tons in 1981. Table 8 presents the evolution of sugar production in Brazil from 1820 to 1981.

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[1]Winthrop P. Carty, "Gasohol: Brazil's Liquid Solar Energy," Americas 33(April 1981):3.

[2]Centrifugal sugar is produced through the modern industrialization process which uses centrifuges to separate the crystals of sugar from the residual molasses. Non-centrifugal sugar is produced by decanting the crystalized molasses.

TABLE 8

THE EVOLUTION OF BRAZIL'S SUGAR
PRODUCTION FROM 1820 TO 1980
(in Metric Tons per Year)

Year	Production of Sugar	Year	Production of Sugar
1820	75,000	1863	238,000
1821	83,000	1864	237,898
1822	91,000	1865	135,109
1823	99,000	1866	150,018
1834	83,000	1867	95,290
1839		1868	113,352
to	82,000[a]	1869	103,078
1844		1870	101,501
1853	138,000	1871	143,975
1854	85,000	1872	157,809
1855	106,000	1873	126,395
1856	88,000	1874	152,937
1857	109,000	1875	102,509
1858	85,000	1876	148,732
1859	120,000	1877	134,464
1860	56,927	1878	120,918
1861	176,000	1879	161,788
1862	118,000	1880	218,582

[a]Average for the period.

TABLE 8-Continued

Year	Production of Sugar	Year	Production of Sugar
1881	194,516	1902	190,125
1882	131,397	1903	198,818
1883	233,885	1904	197,730
1884	329,376	1905	278,850
1885	190,000	1906	272,000
1886	249,821	1907	217,000
1887	270,642	1908	276,000
1888	230,384	1909	294,000
1889	120,000	1910	331,750
1890	175,407	1911	302,270
1891	159,000	1912	336,396
1892	190,900	1913	357,887
1893	207,500	1914	397,092
1894	267,180	1915	400,333
1895	225,000	1916	453,939
1896	175,903	1917	481,522
1897	200,478	1918	516,468
1898	151,495	1919	695,262
1899	175,000	1920	727,679
1900	320,000	1921	860,461
1901	349,088	1922	852,452

TABLE 8-Continued

Year	Production of Sugar	Year	Production of Sugar
1923	862,312	1944	933,336
1924	922,224	1945	920,074
1925	749,632	1946	1,076,412
1926	935,549	1947	1,225,474
1927	833,786	1948	1,410,162
1928	941,999	1949	1,390,830
1929	1,176,076	1950	1,403,010
1930	1,019,769	1951	1,606,685
1931	1,027,517	1952	1,785,017
1932	976,200	1953	2,001,745
1933	1,000,000	1954	2,118,383
1934	994,286	1955	2,072,965
1935	1,013,591	1956	2,268,152
1936	883,730	1957	2,714,154
1937	984,865	1958	3,003,613
1938	655,527	1959	3,108,253
1939	785,582	1960	3,318,719
1940	893,512	1961	3,354,137
1941	854,669	1962	3,238,061
1942	832,018	1963	3,067,838
1943	864,481	1964	3,425,286

TABLE 8-Continued

Year	Production of Sugar	Year	Production of Sugar
1965	4,660,396	1973	6,679,727
1966	3,881,092	1974	6,672,720
1967	4,318,240	1975	6,017,061
1968	4,204,238	1976	6,851,271
1969	4,216,010	1977	8,305,749
1970	5,069,919	1978	7,475,676
1971	5,081,434	1979	6,979,589
1972	5,925,731	1980	7,843,518

SOURCES: Deerr, The History of Sugar, vol. 1, pp. 112-113; Brazil, Secretaria de Planejamento da Presidência da República, Fundação Instituto Brasileiro de Geografia e Estatística, Anuário Estatístico do Brasil (Rio de Janeiro: FIBGE, various issues).

CHAPTER VI.

THE PRODUCTION OF ETHANOL FROM SUGAR CANE IN BRAZIL

Two types of fuel can be used as fuel in combustion engines: ethyl alcohol (ethanol, C_2H_5OH), and methyl alcohol (methanol, CH_3OH). Methanol can be obtained from wood scraps and other fibrous materials, whereas ethanol can be obtained from many agricultural crops that are rich in carbohydrates such as sugar cane, corn, sugar beets, cassava, sorghum, potatoes, and wheat. This study is concerned with the production of ethanol from sugar cane in Brazil.

Table 9 shows that in Brazil sugar cane, cassava and sweet sorghum stand out in terms of ethanol productivity per planted acre. However, throughout history ethanol has been produced using the biomass that is abundant, or more cheaply available in each region.

Modern production of ethanol uses the same basic

TABLE 9

ALCOHOL YIELDS FOR VARIOUS CROPS[a]

Crop	Alcohol Yield (litres/ton)	Crop Yield[b] (tons/ha)	Alcohol Productivity (litres/ha)
Sugar cane	70	66	4,620
Cassava	170	11.94	2,030
Sweet sorghum (irrigated)	60	45[c]	2,700
Molasses	304	. . .	. . .
Wheat	340	.83	282
Maize (corn)	360	1.78	641
Barley	250	1.26	315
Potatoes	110	10.70	1,177
Rice	430	1.57	675
Grapes	130	7.8	1,014

SOURCES: I. G. Prince, "Alcohol Energy Farming," in K. M. W. Howes and R. A. Rummery, eds., Energy and Agriculture (Perth: Commonwealth Scientific and Industrial Research Organization, 1980); United Nations, Food and Agriculture Organization, Production Yearbook (Rome: FAO, 1980).

[a]All these figures are approximations since yields and efficiencies can vary widely.

[b]Unless otherwise noted, these figures refer to Brazil's agriculture productivity in 1980.

[c]Crop yield in Australia in 1979.

process employed since ancient times: the fermentation of carbohydrates formed in the photosynthetic process.[1]

Alcohol as Fuel in Transportation

Since the birth of the automobile ethanol has been used as a fuel in transportation. In 1894, while Karl Benz, Armand Peugeot, Herbert Austin, Henry Ford, Louis Renault and others tried to adapt the recently invented internal combustion engine for transportation purposes, simultaneously in France and Germany research was been carried out to utilize ethanol in the new engines.[2] Starting in 1901, a series of international

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[1]The carbohydrate found in the sugar cane is called sucrose, a disaccharide composed of two monosaccharides: fructose and glucose. One hundred grams of sucrose contains 385 calories. In comparison, there are 65 calories in 100 grams of milk, 197 in 100 grams of steak, and 716 in 100 grams of butter.

[2]Brazil, Ministério da Indústria e do Comércio, Ministério dos Transportes, Estudo do Transporte do Álcool, Relatório 1979 (Brasília: GEIPOT-MT, 1979), pp. 9-10.

conferences were organized to discuss the use of ethanol in motor engines.

The main reason for experimenting with ethanol was the expensiveness of petroleum during the nineteenth century. Only after the great oil discoveries, starting in 1901 in the state of Texas, and in 1908 in Bornéo, ethanol had to compete with abundant and cheap oil-derived motor fuels. Improved refining and distribution methods enlarged oil's advantage overtime.

The first attempts to utilize ethanol as fuel in Brazil occurred in 1923, when the government created an institute specialized in this area which today is known as the Instituto Nacional de Tecnologia, a branch of the Ministry of Industry and Commerce.[1] In 1927, ethanol was sold as fuel in many states of Brazil. In the state of Pernambuco it was called azulina; in Alagoas, a mixture containing 75 percent ethanol and 25 percent

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[1]Ibid., p. 9.

ether was sold as USGA; in Paraíba, ethanol was sold as motorina; and in São Paulo as Cruzeiro do Sul.

During the Great Depression, a number of measures were taken to aid the sugar industry recover itself. In 1931, the Brazilian federal government, pressured by the sugar lobby, decreed that all importers of gasoline would have to mix a minimum of 5 percent ethanol into the fuel sold to the public.[1]

On June 1, 1933, the Institute of Sugar and Alcohol (IAA--Instituto do Açúcar e do Álcool) was formed, and throughout that decade it maintained a strong campaign for the use of ethanol.

In 1938, another decree[2] would make compulsory the addition of ethanol to any gasoline produced in the country.

During the 1930s, the distilling capacity expanded continuously, and the production of ethanol

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[1]This was decree nº 19,117, of February 20, 1931.
[2]This was decree nº 737, of January 23, 1938.

jumped from some 98,000 litres in the 1933-1934 crop year, to 76 million litres in 1942-1943.[1]

During World War II, Brazil was cut off from many outside supplies, and ethanol production reached its peak for the first half of the century. Soon enough the postwar expansion of the Persian Gulf oil production flooded the world energy market with cheap petroleum, and throughout the world fuels from biomass were put aside as a significant source of energy for the next quart of a century. Nevertheless, the production of ethanol in Brazil continued to increase moderately until 1975 (refer to Table 10).

Under cheap oil conditions, Brazil based its transportation strategy on the internal combustion engine, powered by fossil fuel. It embarked on massive road construction programs, even before the country had developed a reliable railroad transportation system. The

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[1] Winthrop P. Carty, "Gasohol: Brazil's Liquid Solar Energy," p. 3.

TABLE 10

PRODUCTION OF HYDROUS AND ANHYDROUS ETHANOL IN BRAZIL FROM 1958 TO 1981 (in Thousands of Litres)

Year	Anhydrous Ethanol	Hydrous Ethanol	Total
1958	280,544	154,752	435,296
1959	343,397	135,325	478,722
1960	188,570	287,698	476,263
1961	181,500	240,329	421,829
1962	132,374	250,212	382,586
1963	111,246	276,268	387,514
1964	62,193	313,378	375,571
1965	305,872	253,186	559,058
1966	362,044	312,826	674,870
1967	432,592	333,125	765,717
1968	171,091	328,100	499,191
1969	98,423	361,246	459,669
1970	233,038	392,311	625,349
1971	394,479	230,267	624,746
1972	400,832	283,141	683,973
1973	319,705	333,107	652,812
1974	215,129	399,808	614,937

TABLE 10-Continued

Year	Anhydrous Ethanol	Hydrous Ethanol	Total
1975	220,340	359,790	580,130
1976	272,352	369,803	642,155
1977	1,087,924	297,724	1,385,648
1978	1,943,455	392,629	2,336,084
1979	2,832,036	618,246	3,450,282
1980	2,172,556	1,503,613	3,676,169
1981[a]	1,500,000	2,750,000	4,250,000

SOURCE: Brazil, Secretaria de Planejamento da Presidência da República, Fundação Instituto Brasileiro de Geografia e Estatística, Anuário Estatístico do Brasil (Rio de Janeiro: FIBGE, various issues).

[a]Preliminary estimates.

growth of the automobile industry became very much linked to the country's strategy and fate. In 1940, petroleum accounted for only 9.2 percent of Brazil's energy consumption, but by 1973 its share had reached a peak of 43.9 percent.[1] Producing only 15 percent of its oil needs, Brazil was particularly vulnerable to the 1973 oil crisis.

The National Alcohol Program

A renewed interest in the production of ethanol was sparkled by the 1973 rise of the price of petroleum (Table 11 shows the evolution of oil prices from 1958 to 1982). But any significant program whose objectives included the partial substitution of oil derivatives with ethanol would have to rely on more than just the residual molasses obtained from the production of sugar

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[1]Júlio Maria Martins Borges, Desenvolvimento Econômico, Política Energética e Álcool (São Paulo: Universidade de São Paulo, 1980), p. 11.

TABLE 11

WHOLESALE PRICE OF PETROLEUM

F.O.B. SAUDI ARABIA (Ras Tanura)

(in Nominal U.S. Dollars per Barrel)[a]

Year	Price of Petroleum	Year	Price of Petroleum
1958	2.08	1971	2.19
1959	1.92	1972	2.38
1960	1.87	1973	3.28
1961	1.80	1974	9.76
1962	1.80	1975	10.72
1963	1.80	1976	11.51
1964	1.80	1977	12.40
1965	1.80	1978	12.70
1966	1.80	1979	16.97
1967	1.80	1980	28.67
1968	1.80	1981	32.50
1969	1.80	1982[a]	33.40
1970	1.80		

SOURCE: International Monetary Fund, International Financial Statistics (Washington, D.C.: IMF, various issues).

[a]One barrel is equivalent to 42 gallons, or 159 litres.

as the main input.

On November 14, 1975, the National Alcohol Program (Proálcool) was established in Brazil, aimed at increasing the production of ethanol to be used as fuel utilizing molasses and sugar cane directly as inputs.[1]

The Proálcool, as defined by its specific legislation,[2] consists of incentives to private enterprises in the form of subsidized loans given to government approved projects, and a price policy that should stimulate the production of ethanol. It also consists of incentives given to the general public to stimulate the adoption of the new technology that enables the use of straight hydrous ethanol (91.1 to 93.9 percent pure, the balance being water) as the sole fuel.

In a first stage of the program, there was no readily available technology for adapting the Otto cycle

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[1]Chapter VII presents a summarized sequence of the historical events that led to the creation of the National Alcohol Program.

[2]A section dealing with the legislation of the Proálcool is presented in Chapter VII.

engine for the use of straight ethanol, therefore most of the ethanol had to be produced in its anhydrous state (nearly water-free, or 199-proof) to allow for the blending with gasoline.[1]

In a second stage of the program, when the technology to use straight hydrous ethanol was disseminated, the government provided greater incentives for the domestic production of hydrous ethanol, targeted for consumption in all-ethanol engines.[2]

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[1]Unlike the gasohol sold in the United States, which is composed of nine parts of gasoline and one part of 199-proof ethanol, the gasohol marketed in Brazil is combined in a ratio of 8 to 2, which is also the technical limit to avoid engine malfunction.

[2]Under the Proálcool, the government guarantees the purchase of ethanol produced by approved projects which is in accordance with the following specifications: for anhydrous ethanol the minimum alcohol content must be 99.3 percent, with the maximum of 0.7 percent of water; for hydrous ethanol, to be used exclusively in Otto cycle engines, a maximum alcohol content of 93.9 percent, and a minimum of 91.1 percent, the balance being water. See Brazil, Ministério da Indústria e do Comércio, Ministério dos Transportes, Estudo do Transporte do Álcool e Acompanhamento do Programa Nacional do Álcool--Proálcool, Relatório de Atividades de 1981 (Brasília: GEIPOT-MT, 1981), p. 12.

Ambitious goals were established for the total annual production and use of alcohol. But goals, even being so bold, were achieved often a year in advance. In 1982, nearly 5.3 billion litres of ethanol were produced, representing 14 percent of all transportation fuels used in Brazil. The goal for 1985 is 10.7 billion litres of ethanol, corresponding to 23 percent of all transportation fuels to be consumed in that year.[1]

In order to achieve the government goals, the following policy instruments were defined under the Proálcool:

1) Early government investment in research and development of the appropriate technology for adapting the Otto cycle engine for ethanol use;

2) Twelve-year industrial investment loans provided at highly negative real interest rates to projects aimed

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[1]Brazil, Ministry of Industry and Commerce, Secretariat of Industrial Technology, Assessment of Brazil's National Alcohol Program (Brasília: MIC-SIT, 1981), p. 8.

at increasing the production of ethanol;[1]

3) Establishment of protocol agreements between the government and the automobile industry determining goals for the production of all-ethanol passenger cars, and establishing limits for the conversion of existing gasoline engines into ethanol engines;

4) The fixation of the final price of ethanol to consumers at roughly 50 percent of the price of gasoline (fuel prices are controlled by the government in Brazil), with the guarantee not to exceed 65 percent of this price so as to overcome the greater fuel consumption of ethanol. Additional advantages were provided in the form of longer financing terms for vehicle purchases, and a 50 percent

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[1]Discussions about the level of subsidized interest rates, and other conditions of Proálcool's lines of credit can be found in Brazil, Ministry of Industry and Commerce, Secretariat of Industrial Technology, Assessment of Brazil's National Alcohol Program, pp. 7-8; and Brazil, Ministério da Indústria e do Comércio, Ministério dos Transportes, Estudo do Transporte do Álcool--1981, pp. 15-16. In this study, only the average values of subsidized interest rates are considered in each period.

reduction in vehicle registration fees;

5) The price of sugar cane paid to producers, and the price of ethanol and sugar received by distillers and owners of sugar factories should be set at levels consistent with the established goals of ethanol production.

CHAPTER VII.

A BRIEF HISTORY OF THE CREATION OF BRAZIL'S NATIONAL ALCOHOL PROGRAM

The use of ethanol as a fuel and as an input to the chemical industry was widely known in Brazil before 1973. But the structure of energy prices that prevailed before the 1973 oil crisis could not allow the expansion of the ethanol production in Brazil. The price of petroleum throughout the 1960s was US$1.80 per barrel,[1] and in 1973 it was still US$3.30 per barrel (see Table 11 in Chapter VI).

According to former President Ernesto Geisel,[2] who is also well-known as an expert in the petrochemical industry:

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[1] One barrel is equivalent to 42 gallons, or 159 litres.

[2] Geisel's tenure at the presidency lasted from January 15, 1974 to March 15, 1979.

Na indústria do petróleo o álcool era visto, de certa forma, como um combustível inconveniente, por motivos econômicos, não obstante o esforço que se fazia para um equacionamento racional da questão. Em suma, o álcool que se misturava à gasolina era o resíduo que sobrava, após esgotados todos os seus mercados, inclusive o da exportação do melaço que era a matéria-prima exclusiva para sua produção.[1]

[In the petroleum industry of Brazil, because of economic factors the ethanol was regarded in some ways as an inconvenient fuel, in spite of all the efforts to rationally solve the question. In the end, the volume of ethanol added to gasoline was the residue left after all of its possible markets were exhausted, including the export market of residual molasses which were the exclusive raw-input used in the production of ethanol].

Indeed, while at the head of Petrobrás--the state-owned petroleum industry--former President Geisel made strong efforts to increase the proportion of ethanol added to gasoline,[2] which was at the time lower than five percent (Table 12 shows the evolution of the propor-

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[1]Ernesto Geisel, 25 September 1983, personal letter.

[2]Specially during the period between the end of 1922 and the middle of 1973, when there were indications of the rise in petroleum prices (see Table 11).

TABLE 12

PROPORTION OF ANHYDROUS ETHANOL
CONTAINED IN THE GASOHOL (GASOLINE "A")
CONSUMED IN BRAZIL FROM
1939 TO 1980

Year	Consumption of Gasohol (in Thousands	Anhydrous Ethanol in the Mixture of Litres)	Percentage
1939	578,808	35,265	6.1
1940	615,826	30,762	5.0
1941	687,593	72,695	10.5
1942	449,095	60,592	13.5
1943	317,425	19,366	6.1
1944	380,299	25,832	6.8
1945	551,333	11,461	2.1
1946	994,219	12,207	1.2
1947	1,220,566	46,131	3.8
1948	1,472,981	59,507	4.0
1949	1,755,972	61,219	3.5
1950	2,085,047	11,422	0.5
1951	2,510,157	19,099	0.8
1952	3,044,661	61,204	2.0
1953	3,311,814	112,998	3.4
1954	3,336,081	124,157	3.7

TABLE 12-Continued

Year	Consumption of Gasohol (in Thousands	Anhydrous Ethanol in the Mixture of Litres)	Percentage
1955	3,384,278	169,447	5.0
1956	3,513,824	95,427	2.7
1957	3,448,572	158,824	4.6
1958	3,812,398	277,323	7.3
1959	3,840,853	304,650	7.9
1960	4,285,930	232,769	5.4
1961	4,484,760	130,687	2.9
1962	5,064,447	139,843	2.8
1963	5,493,492	62,809	1.0
1964	5,997,375	82,752	1.4
1965	5,982,496	224,798	3.8
1966	6,573,741	338,301	5.1
1967	7,144,976	369,495	5.2
1968	8,052,300	191,300	2.4
1969	8,492,400	31,800	0.4
1970	9,340,480	183,606	2.0
1971	10,074,489	253,836	2.5
1972	11,217,444	391,142	3.5
1973	12,933,403	308,812	2.4
1974	13,840,674	190,170	1.4

TABLE 12-Continued

Year	Consumption of Gasohol (in Thousands	Anhydrous Ethanol in the Mixture of Litres)	Percentage
1975	14,354,518	162,165	1.1
1976	14,546,411	171,572	1.2
1977	13,976,082	638,977	4.6
1978	15,100,030	1,504,119	10.0
1979	15,537,571	2,219,084	14.3
1980	15,937,264	2,253,108	14.1

SOURCES: Brazil, Secretaria de Planejamento da Presidência da República, Fundação Instituto Brasileiro de Geografia e Estatística, Anuário Estatístico do Brasil, various issues; Brazil, Ministério da Indústria e do Comércio, Ministério dos Transportes, Estudo do Transporte do Álcool--1981, p. 30.

tion of anhydrous ethanol added to gasoline from 1939 to 1982).

When Ernesto Geisel took the oath of office, the petroleum industry was in the midst of a crisis without precedents. Under his guidance many studies were developed to analyze Brazil's energy problems, and to implement in a rational and definitive way the addition of ethanol to gasoline. These initiatives were coordinated in the Ministry of Industry and Commerce.

However, during 1974 the price of sugar in the international market soared to US$1,500 per metric ton.[1] Under these conditions there were very dim economic incentives in the short-run for converting sugar cane into ethanol. In 1974, the value added by the sugar cane agroindustry is estimated at US$3.9 billion (valued at the international prices in that year). This value would correspond to approximately five percent of Brazil's

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[1]For comparison, in October of 1983 the price of sugar F.O.B. New York was quoted at US$220 per metric ton.

gross domestic product (measured in dollars) in 1974.[1]

The expected increase in the world production of sugar cane, as a result of the 1974 rise in sugar prices, prompted Brazilian experts to recommend firm measures to protect the local sugar industry from a subsequent drop in sugar prices.

From the private sector the first outcry came from the quarters of Lamartine Navarro Jr. On April 20, 1974, Navarro Jr. addressed a study[2] to the then President of Brazil's National Petroleum Council (CNP), Araken de Oliveira, suggesting that incentives be given for the production of ethanol directly from sugar cane.

In the government, the general concern in 1974 is best expressed by former President Geisel, when he recalls that:

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[1]Getúlio Valverde de Lacerda to Paulo Vieira Belotti and Ernesto Geisel, 8 September 1983, personal letter.

[2]Lamartine Navarro Jr., Fotossíntese como fonte energética (São Paulo: Associação Brasileira dos Distribuidores de Gás Liquefeito de Petróleo, 1974).

De minha parte, estava persuadido de que, como no passado, o preço do açúcar iria cair e de que a produção de álcool poderia proporcionar maior estabilidade econômica a esse importante setor da economia nacional; além de dar contribuição ao nosso balanço de pagamentos, pela economia na importação de petróleo, num setor que quase nada demandava em moeda estrangeira para sua expansão. Julgava mesmo que naquela quadra de nossa história econômica esse setor era um dos mais adequados para contribuir para o desenvolvimento e para a criação de empregos no nosso País. [1]

[Given the facts, I was convinced that, as it had occurred in the past, the price of sugar would drop and the production of ethanol could provide greater economic stability to this important segment of our national economy. In addition, the production of ethanol could significantly improve our balance of payments, through the substitution of imported petroleum, demanding very little foreign capital for its expansion. It was my judgement at that time of our economic history that this sector was one of the most suited to carry on Brazil's development process, and to create more jobs in our country].

Efforts in the federal government to develop policies to protect and expand the role of the sugar cane industry continued to be monitored by the Ministry

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[1] Ernesto Geisel, 25 September 1983, personal letter.

of Industry and Commerce (MIC). Paulo Vieira Belotti, then Secretary-General of the MIC, was designated by the Council of Economic Development (CDE--Conselho de Desenvolvimento Econômico)[1] to direct and coordinate studies needed for the creation of a program geared at the intensified use of ethanol as fuel.

Many proposals were made by the MIC, which later became law by the decree nº 75,966 of July 11, 1975, and the decree-law nº 1,409 of the same date. Some of their provisions included:

1) The parity of prices of anhydrous ethanol and standard crystal sugar, on the basis of 44 litres for each 60 kilograms;

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[1]The membership of the CDE was formed by: Ernesto Geisel, President; Mário Henrique Simonsen, Minister of Finance; Alysson Paulinelli, Minister of Agriculture; Severo Fagundes Gomes, Minister of Industry and Commerce; Shigeaki Ueki, Minister of Mines and Energy; João Paulo dos Reis Velloso, Minister of the Secretariat of Planning; and Maurício Rangel Reis, Minister of the Interior.

2) The price of anhydrous ethanol equivalent to the price of gasoline, after the deduction of expenses with mixing;

3) The inclusion of anhydrous ethanol added to gasohol under the regiment of the Unified Tax on Lubricants and Fuels (Imposto Único sobre Lubrificantes e Combustíveis Líquidos e Gasosos), and its exemotion;

4) The establishment of credit lines to finance the installation and the expansion of existing ethanol distilling plants annex to sugar mills, using resources from IAA's export fund.

For all practical purposes the decree nº 75,966 was not put into effect, although it had the merit of defining the skeleton for the creation of the National Alcohol Program later on.

At that time, a special workshop was established in the Ministry of Industry and Commerce (MIC) to draft a new decree. The group was formed with members of the MIC and representatives from the Secretariat of Planning

(SEPLAN), the Ministry of Agriculture (MA), the Ministry of Mines and Energy (MME), the National Petroleum Council (CNP), and the Institute of Sugar and Alcohol (IAA).[1] The draft of a new decree was handed by the Secretary-General of the MIC, Paulo Vieira Belotti, to the Secretary-General of the Council of Economic Development (CDE), Minister João Paulo dos Reis Velloso, on October 22, 1975 during a meeting at the MIC's headquarters.

Meanwhile, already on October 9, 1975, former President Geisel anticipated the creation of the National Alcohol Program during a televised speech when he said:

> O Governo decidiu, também, aprovar um Programa Nacional do Álcool, destinado a permitir o uso deste,

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[1]The workshop had the following membership: Paulo Vieira Belotti, Coordinator-General, and Secretary-General of the MIC; Getúlio Valverde de Lacerda, Coordinator of the workshop (MIC); Ivo Simas Moreira (SEPLAN); Amaury Terezino dos Santos Fassy (SEPLAN); Antônio Lício (MA); Adalberto Telles (MME); Américo de Moraes Novaes (CNP/MME); Antonio Rodrigues da Costa e Silva (IAA/MIC); Ana Terezinha de Jesus Souza (IAA/MIC); Fernando Carlos de Toledo Piza (IAA/MIC); and Romeu Boto Dantas (COPERBO).

progressivamente, como combustível, em proporção da ordem de 20 porcento, assim como sob a forma de matéria-prima para a indústria química.

O conjunto de medidas a serem baixadas em breve, para tal fim, compreende a compra de álcool, pela Petrobrás, aos novos níveis de preço (paridade com o preço do açúcar cristal), os estímulos financeiros à produção de cana adicional e à montagem de destilarias anexas e autônomas.

Haverá, também, programas especiais de apoio à produção de álcool de outras fontes--mandioca e batata doce--notadamente em áreas novas. [1]

[The Government has also decided to approve a National Alcohol Program geared at progressively increase the use of ethanol as fuel, in the proportion of approximately 20 percent, as well as its use as an input to the chemical industry.

A number of measures are going to be taken soon towards this end, providing for the purchase of ethanol by Petrobrás at the new price levels (parity with the price of crystal sugar), and for financial incentives for the production of more sugar cane and the installation of distilling plants.

There will be also special programs to stimulate the production of ethanol from other sources--cassava and sweet potatoes--with emphasis in new areas of development].

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[1]Getúlio Valverde de Lacerda to Paulo Vieira Belotti and Ernesto Geisel, 8 September 1983, personal letter.

However, if a consensus had been reached at the technical level, a few points were still under debate in the political arena.

The Ministry of Agriculture (MA) seeked a greater participation for cassava as an input in the production of ethanol. The justification was based on a study prepared by the Secretariat of Industrial Technology of the MIC, which also supported the idea.

The Ministry of Mines and Energy (MME) wanted to administer the whole commercialization of ethanol, through the CNP and Petrobrás, including the net revenues that would eventually be accrued.

The Ministry of the Interior, which participated in the discussions at the CDE, seeked more emphasis on the incentives given to the northeastern region of Brazil.

All these controversies were introduced in the many drafts of the decree submitted to the CDE, during an extraordinary meeting at the Granja do Riacho Fundo on November 8, 1975. During the course of this meeting the CDE approved the final draft of the decree.

On November 14, 1975, then President Ernesto Geisel signed the decree nº 76,593 officially creating the National Alcohol Program. The Proálcool defined the following targets (among others):

1) To increase the domestic production of energy based on renewable resources;

2) To stimulate technological improvements in the sugar cane agroindustry;

3) To promote social and economic development, specially in rural areas.

Legislation

The legislation related to the National Alcohol Program is presented below in chronological order:

1) Decree nº 76,593, of November 14, 1975, enables the rapid expansion of the ethanol production and its use

as a fuel in transportation, and as a raw-input to the chemical industry;

2) Decree nº 80,762, of November 18, 1977, consolidates the measures established at the creation of the National Alcohol Program;

3) Decree nº 82,476, of October 23, 1978, establishes standards for the trade of ethanol as fuel;

4) Decree nº 83,700, of July 5, 1979, supersedes decree nº 80,762 and defines other execution procedures for the Proálcool. It creates the National Alcohol Council (CNAL--Conselho Nacional do Álcool) and the National Executive Commission on Alcohol (CENAL--Comissão Executiva Nacional do Álcool), and determines the subordination of all government decisions related to the Proálcool to the approval of CNAL;

5) Decree nº 85,678, of January 30, 1981, modifies decree nº 82,476.

6) Decree nº 85,698, of February 4, 1981, sets criteria for the registration of hydrous ethanol distilling plants with production capacities under 5,000

litres per day;

7) Decree nº 87,813, of November 16, 1982, modifies the criteria for the concession of incentives to the alcohol industry.

A number of other regulatory acts have been released since the creation of the Proálcool:

1) Portaria of the CNP nº 059, of February 4, 1980, defines the procedures for the sale of hydrous ethanol;

2) Resolution of the CNAL nº 06/80, of March 18, 1980, defines norms for the storage and transportation of hydrous ethanol;

3) Resolution of the National Commission on Energy (CNE--Comissão Nacional de Energia) nº 002, of July 2, 1980, limits the price of hydrous ethanol used as fuel to a maximum of 65 percent of the price of gasoline;

4) Resolution of the CNP nº 17/80, of October 30, 1980, defines procedures for the use of hydrous ethanol as fuel and as an input to the chemical industry;

5) Resolution of the National Monetary Council (CMN--Conselho Monetário Nacional) nº 671/80, of December 17,

1980, establishes new subsidized interest rates charged on loans given for the installation of ethanol distilling plants;

6) Portaria of the CNP nº 588, of December 22, 1980, defines the work schedule of gas stations nation-wide;

7) Act of the CENAL nº 437/81, of February 1981, defines a simplified procedure for the registration of hydrous ethanol distilling plants with production capacities under 5,000 litres per day;

8) Portaria of the CNP nº 157, of April 22, 1981, for the north and northeast regions, and portaria of the CNP nº 245, of June 30, 1981, for the central and south regions, determine that the ethanol-gasoline mixture shall contain a minimum of twelve percent of ethanol;

9) Normative instruction of the Ministries of Mines and Energy, Industry and Commerce, Transportation, and Justice nº 01/81, of May 19, 1981, determines the nation-wide compulsory use of identification stamps on vehicles using straight hydrous ethanol as fuel;

10) Portaria of the CNP nº 368, of October 2, 1981, modifies portaria nº 157 and determines a minimum of 20 percent of ethanol in the ethanol-gasoline mixture used as fuel in the north and northeast regions starting on October 5, 1981;

11) Resolution of the CNE, of November 28, 1981, authorizes the CNP to determine the percentage of ethanol added to gasoline, provided it is between 12 and 20 percent;

12) Resolution of the CNP, of May 12, 1982, fixes the minimum consumption of ethanol by the chemical industry at 350 million litres in 1982.

Administration of the National Alcohol Program (Proálcool)

The administration of the Proálcool is diluted among many branches of the federal government. The bodies responsible for the coordination of the Proálcool are:

1) The National Alcohol Council (CNAL--Conselho Nacional do Álcool);

2) The Central Bank of Brazil (BC--Banco Central).

The bodies responsible for its direction are:

1) The National Executive Commission on Alcohol (CENAL--Comissão Executiva Nacional do Álcool);

2) The National Petroleum Council (CNP--Conselho Nacional do Petróleo).

The bodies responsible for its execution are:

1) The Institute of Sugar and Alcohol (IAA--Insituto do Açúcar e do Álcool);

2) The private and government-controlled banks;

3) Fuel distributors: Petrobrás and others.

Figure 2 shows the distribution of functions and the hierarchy of institutions involved in the administration of the Proálcool.

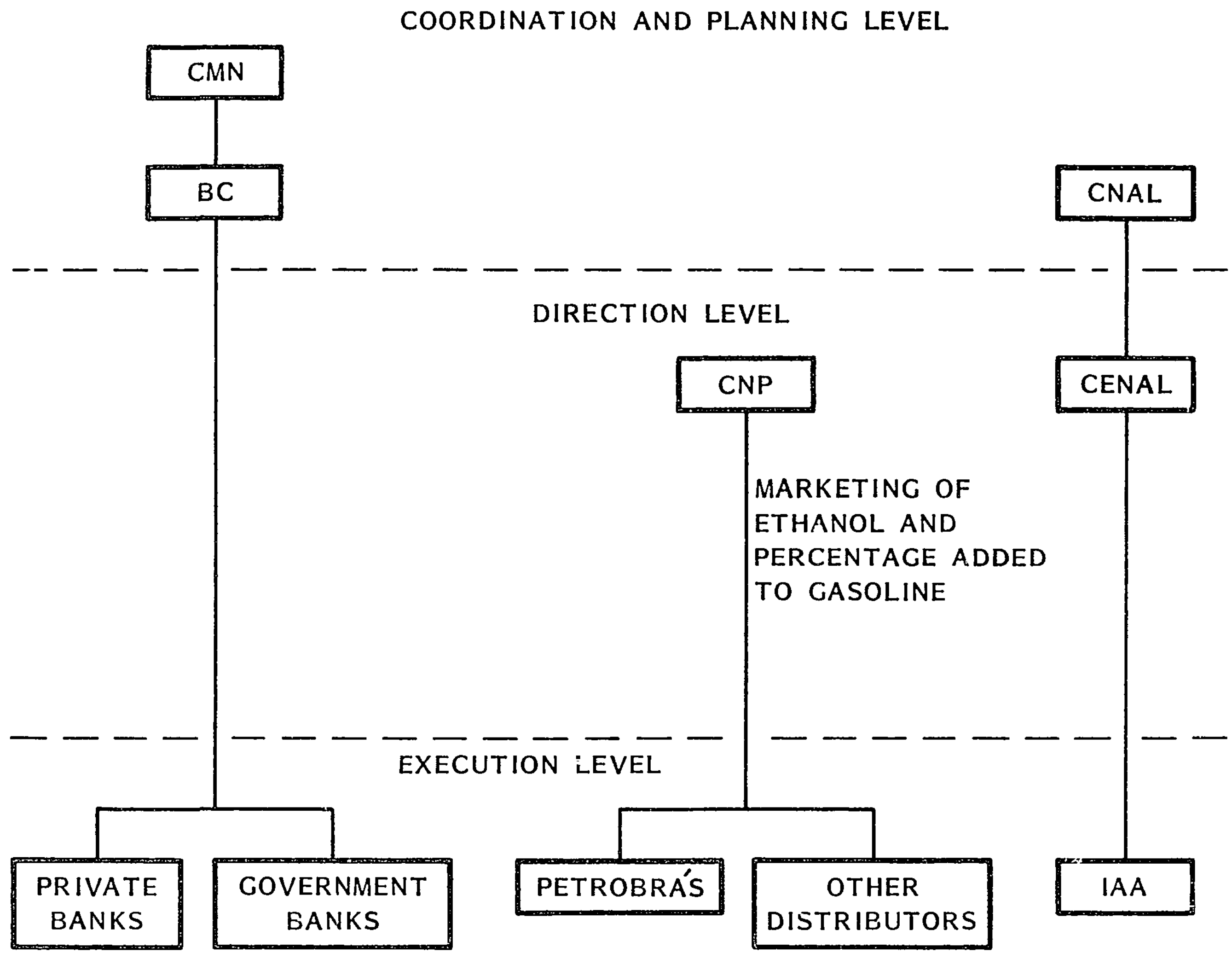

Figure 2. Institutions involved in the administration of the Proálcool

PART II.

AN ECONOMETRIC MODEL OF BRAZIL'S SUGAR AND ETHANOL INDUSTRIES

CHAPTER VIII.

REVIEW OF THE LITERATURE

Although there is a vast list of studies dealing with the production of sugar cane, sugar, and ethanol in Brazil, only a small fraction of these studies embark in modelling efforts. Some of the topics most frequently analyzed include the specification of production costs and evolution of prices, the nature of technological improvements, the evolution of productivity, and the structure of input ownership. Along these lines, the most recent and complete studies are the ones undertaken by Borges,[1] Silva,[2] Tanno,[3] Carvalho and Craca,[4]

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[1]Júlio Maria Martins Borges, Viabilidade Econômica da Produção de Cana e Álcool no Brasil: Uma Abordagem Dinâmica (São Paulo: Copersucar, 1982).

[2]J. G. da Silva, "Custo de produção e níveis de preço em cana-de-açúcar," Brasil Açucareiro 93(1979):38-50.

[3]A. R. Tanno, "Análise econômica e de produtividade da colheita mecânica na Companhia Agropecuária Rio Pardo, safra 77/78," Brasil Açucareiro 92(1978):5-8.

[4]L. C. C. Carvalho and L. R. Craca, "Produtividade

Neves,[1] Melo,[2] Mattuella,[3] Pinazza and Pelin,[4] and Wanderley.[5]

Modelling Efforts

There have been attempts to estimate structural economic relationships dealing with sugar and sugar cane,

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agrícola da cana-de-açúcar no estado de São Paulo," Brasil Açucareiro 88(1976):36-59.

[1]A. A. Neves, "Estudo econômico e agricola dos plantios manual e motomecanizado da cana-de-açúcar," Anais da Escola Superior de Agricultura "Luiz de Queiroz" 30(1973): 105-127.

[2]Fernando B. H. de Melo, "Disponibilidade de tecnologia entre produtos da agricultura brasileira," Revista de Economia Rural 18(1980):221-249.

[3]J. L. Mattuella, "Economic impact of alcohol production on agriculture in southern Brazil" (Ph.D. dissertation, Ohio State University, 1980).

[4]A. H. Pinazza and E. R. Pelin, "Uma análise crítica da produtividade na agroindústria canavieira," in Anais do Congresso Nacional da Sociedade de Técnicos Açucareiros do Brasil (Rio de Janeiro: STAB, 1981), pp. 319-351.

[5]M. N. B. Wanderley, Capital e propriedade fundiária: suas articulações na economia açucareira de Pernambuco (Rio de Janeiro: Paz e Terra, 1978).

but no one with ethanol.

Ribeiro et al.[1] estimated planted area and yields of sugar cane in the state of Minas Gerais using linear and log-linear equations. In the estimation of the planted area equation, the log-linear functional form presented the better statistical fit, whereas for the yield response equation the linear form had the better performance. In both equations the variable with the largest t-ratio was trend, followed by the price of sugar cane lagged by two periods which was significant at the five percent level. The price elasticity of supply of sugar cane was estimated at 1.43, using data for the years 1947 to 1970.

Alcantara and Pratto[2] estimated returns to scale and input elasticities of production of sugar cane using cost functions based on Cobb-Douglas production functions.

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[1] A. B. Ribeiro et al., "Relações estruturais de oferta de cana-de-açúcar," Experientiae 25(1979):1-17.

[2] R. Alcantara and A. A. Pratto, "Returns to scale and input elasticities for sugar cane: the case of São Paulo, Brazil," American Journal of Agricultural Economics 55(1973):577-583.

Their results showed increasing returns to scale up to 161,000 tons of sugar cane harvested, and decreasing returns to scale thereafter. It follows that given the existing technology the expansion of sugar cane production in farms beyond 161,000 tons per year is not likely to reduce average costs, due to the presence of diseconomies of scale. The reported input elasticities of production were 0.340 for labor, 0.285 for land, 0.351 for fertilizer, 0.113 for pesticides, and -0.089 for machinery and equipment.

Barros et al.[1] studied the domestic and export markets for sugar using an econometric model. Results indicated that producers of sugar are not very responsive to price changes in the short-run (the short-run price elasticity of supply was estimated at 0.25). However, in the long-run, the estimated price (lagged by two periods) elasticity of supply was significantly

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[1]W. J. Barros et al., "Análise econométrica dos mercados interno e de exportação de açúcar," Revista Ceres 24(1977):484-496.

larger (3.94). With respect to the demand for sugar, the estimated (current) price elasticity of per capita demand was 0.32, and the per capita income elasticity of per capita demand was estimated at 0.53. The low values estimated for the price and income elasticities of per capita demand suggest the inexistence of close substitutes for sugar in Brazil.

In terms of Brazil's export demand for sugar, the study concluded that the export price elasticity of demand was 1.2, in the short-run. The data used is from 1947 to 1973.

Summary

In summary, there is a vast amount of literature dealing with the production of sugar cane, sugar, and ethanol in Brazil. However, most of these studies do not quantify the structural relationships of these three subsectors of the Brazilian economy. A few studies have been carried out to estimate production functions, cost functions, input elasticities of production, and price elasticities of supply and demand. These studies are reviewed above.

The econometric model developed in this study is an attempt to use the most up-to-date data available to systematically estimate the economic relationships between the sugar cane, sugar, and ethanol industries of Brazil.

CHAPTER IX.

THE PROPOSED MODEL

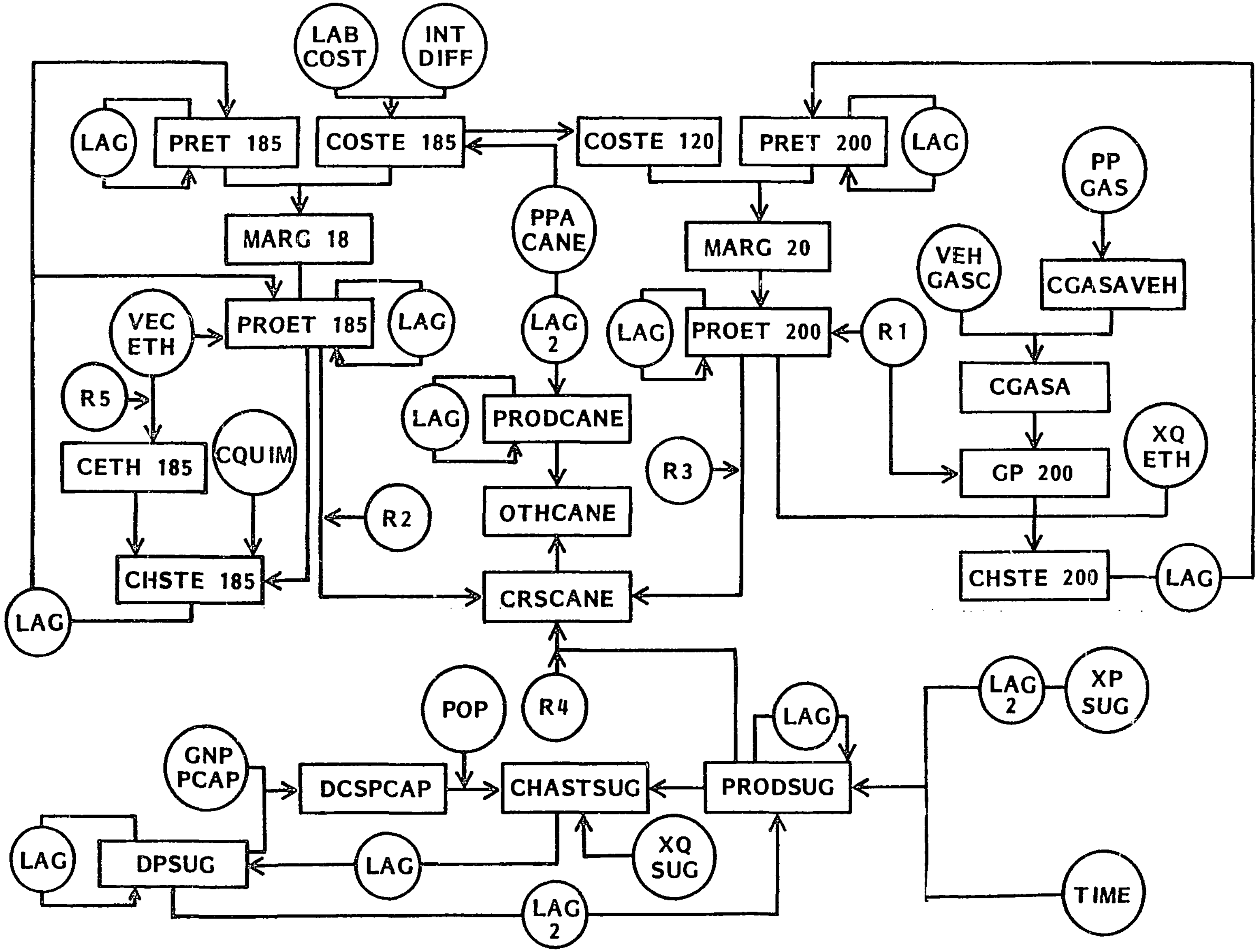
The theoretical model is composed of four subsector models which try to depict the market relationships for sugar cane, sugar, hydrous ethanol, and anhydrous ethanol. All the structural relationships defined in the model are linear, and refer to <u>domestic</u> commodity demands and supplies. Export demands, when considered, are assumed to be exogenous to the model.

Figure 3 presents a flow diagram of the hypothesized interrelationships between the variables in the model. The theoretical model contains 21 endogenous and 28 predetermined variables (10 lagged endogenous and 18 exogenous variables).

Hypothesized Specification of Equations

The theoretical system of equations is block-recursive in the sugar, hydrous and anhydrous ethanol subsectors. Variable definitions follow the equations. The

Figure 3. Flow diagram of the theoretical model


LAB COST
INT DIFF
LAG
PRET 185
COSTE 185
COSTE 120
PRET 200
LAG
PP GAS
MARG 18
PPA CANE
MARG 20
VEH GASC
CGASAVEH
VEC ETH
PROET 185
LAG
LAG 2
LAG
PROET 200
R1
R5
CGASA
LAG
PRODCANE
CETH 185
CQUIM
R3
GP 200
XQ ETH
R2
OTHCANE
CHSTE 185
CRSCANE
CHSTE 200
LAG
LAG
LAG 2
XP SUG
POP
R4
LAG
GNP PCAP
DCSPCAP
CHASTSUG
PRODSUG
LAG
DPSUG
LAG
XQ SUG
LAG 2
TIME

behavior of the sugar cane, sugar, and ethanol industries of Brazil is hypothesized as follows:

1) Sugar

a) Domestic per capita demand function for sugar:

$$DCSPCAP = A1 + A2(GNPPCAP) + A3(DPSUG) + e1 \quad (1.1)$$

b) Domestic supply function of sugar:

$$PRODSUG = B1 + B2(PRODSUG_{t-1}) + B3(DPSUG_{t-2})$$

$$B4(XPSUG_{t-2}) + e2 \quad (1.2)$$

c) Equilibrium condition:

$$CHASTSUG = PRODSUG - (DCSPCAP)(POP) - XQSUG \quad (1.3)$$

d) Pricing equation:

$$DPSUG = C1 + C2(DPSUG_{t-1}) + C3(CHASTSUG_{t-1})$$

$$+ e3 \quad (1.4)$$

2) Hydrous ethanol

a) Domestic demand for hydrous ethanol as fuel:

$$CETH185 = (VECETH)(R5) \quad (2.1)$$

b) Domestic supply function of hydrous ethanol:

$$PROET185 = D1 + D2(PROET185_{t-1}) + D3(MARG18) + D4(VECETH) + D5(CHSTE185_{t-1}) + e4 \qquad (2.2)$$

c) Equilibrium condition:

$$CHSTE185 = PROET185 - CETH185 - CQUIM \qquad (2.3)$$

d) Support equations:

$$COSTE185 = E1 + E2(LABCOST) + E3(INTDIFF) + E4(PPACANE) + e5 \qquad (2.4)$$

$$PRET185 = F1 + F2(PRET185_{t-1}) + F3(CHSTE185_{t-1}) + e6 \qquad (2.5)$$

$$MARG18 = PRET185 - COSTE185 \qquad (2.6)$$

3) Anhydrous ethanol

a) Domestic demand for anhydrous ethanol:

$$GP200 = (R1)(CGASA) \qquad (3.1)$$

b) Domestic supply function of anhydrous ethanol:

$$PROET200 = G1 + G2(PROET200_{t-1}) + G3(MARG20)$$

$$+ G4(R1) + G5(CHSTE200_{t-1}) + e7 \quad (3.2)$$

c) Equilibrium condition:

$$CHSTE200 = PROET200 - GP200 - XQETH \quad (3.3)$$

d) Support equations:

$$COSTE200 = (COSTE185)/0.955 \quad (3.4)$$

$$PRET200 = H1 + H2(PRET200_{t-1}) + H3(CHSTE200_{t-1})$$

$$+ e8 \quad (3.5)$$

$$MARG20 = PRET200 - COSTE200 \quad (3.6)$$

$$CGASA = (CGASAVEH)(VEHGASC) \quad (3.7)$$

$$CGASAVEH = J1 + J2(PPGAS) + e9 \quad (3.8)$$

4) Sugar cane

a) Demand for sugar cane:

$$CRSCANE = (R2)(PROET185) + (R3)(PROET200)$$

$$+ (R4)(PRODSUG) \quad (4.1)$$

b) Supply of sugar cane:

$$PRODCANE = K1 + K2(PRODCANE_{t-1}) + K3(PPACANE_{t-2}) + e10 \qquad (4.2)$$

c) Equilibrium condition:

$$OTHCANE = PRODCANE - CRSCANE \qquad (4.3)$$

where:

CETH185 = is the quantity of hydrous ethanol consumed as fuel in period t (in thousands of litres per year);

CGASA = is the quantity of gasohol (anhydrous ethanol and gasoline mixture) consumed as fuel in period t (in thousands of litres per year);

CGASAVEH = is the quantity of gasohol consumed as fuel per vehicle in period t (in thousands of litres per vehicle per year);

CHASTSUG = is the change in the volume of stocks of sugar in period t (in metric tons per year);

CHSTE185 = is the change in the volume of stocks of hydrous ethanol in period t (in thousands of litres per year);

CHSTE200 = is the change in the volume of stocks of anhydrous ethanol in period t (in thousands of litres per year);

COSTE185 = is the cost of producing hydrous ethanol in period t (in cruzeiros of 1980 per litre);[1]

COSTE200 = is the cost of producing anhydrous ethanol in period t (in cruzeiros of 1980 per litre);

CQUIM = is the quantity of hydrous ethanol consumed by the chemical industry in period t (in thousands of litres per year);

CRSCANE = is the total quantity of sugar cane crushed by sugar factories and ethanol distilling

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[1]The values of all the variables expressed in cruzeiros were deflated using the wholesale price index, products for domestic use, all commodities from Fundação Getúlio Vargas, Instituto Brasileiro de Economia, <u>Conjuntura Econômica</u> (Rio de Janeiro: IBRE, various issues).

plants in period t (in metric tons per year);

DCSPCAP = is the per capita domestic consumption of sugar in period t (in metric tons per person per year);

DPSUG = is the domestic price of sugar in period t (in cruzeiros of 1980 per kilogram);

GNPPCAP = is the per capita gross national product in period t (in millions of cruzeiros of 1980 per person per year);

GP200 = is the quantity of anhydrous ethanol mixed with gasoline in period t (in thousands of litres per year);

INTDIFF = is the difference between the market interest rate and the subsidized interest rate charged by the Proálcool in period t (in percent);

LABCOST = is the cost of labor in period t (cost of one month's full-time labor employed at the minimum wage rate, in cruzeiros of

1980);

MARG18 = is the profit margin inthe production of hydrous ethanol in period t (in cruzeiros of 1980 per litre per year);

MARG20 = is the profit margin in the production of anhydrous ethanol in period t (in cruzeiros of 1980 per litre per year);

OTHCANE = is the quantity of sugar cane crushed for non-centrifugal sugar and liquor in period t (in metric tons per year);

POP = is the population of Brazil in period t (in number of persons residing in Brazil in each year);

PPACANE = is the price paid for sugar cane by sugar factories and distilling plants (in cruzeiros of 1980 per metric ton);

PPGAS = is the price of gasoline or gasohol paid by consumers in period t (in cruzeiros of 1980 per litre per year);

PRET185 = is the price received by distillers for hydrous ethanol in period t (in cruzeiros of 1980 per litre per year);

PRET200 = is the price received by distillers for anhydrous ethanol in period t (in cruzeiros of 1980 per litre per year);

PRODCANE = is the quantity of sugar cane harvested in period t (in metric tons per year);

PRODSUG = is the quantity of centrifugal sugar produced in period t (in metric tons per year);

PROET185 = is the volume of hydrous ethanol produced in period t (in thousands of litres per year);

PROET200 = is the volume of anhydrous ethanol produced in period t (in thousands of litres per year);

R1 = is the proportion of anhydrous ethanol added to gasoline in period t (in percent);

R2 = is the technical coefficient for the use of sugar cane in the production of hydrous ethanol in period t (in metric tons of sugar cane needed to produce one thousand litres of hydrous ethanol--see details below in this chapter);

R3 = is the technical coefficient for the use of sugar cane in the production of anhydrous ethanol in period t (in metric tons of sugar cane needed to produce one thousand litres of anhydrous ethanol);

R4 = is the technical coefficient for the use of sugar cane in the production of sugar in period t (in metric tons of sugar cane needed to produce one metric ton of centrifugal sugar, discounting for ethanol from molasses);

R5 = is the average consumption of hydrous ethanol per vehicle in period t (in thousand litres per vehicle per year);

TIME = is a trend variable;

VECETH = is the average number of vehicles that utilize hydrous ethanol as fuel in period t (in units per year);

VEHGASC = is the average number of vehicles that utilize gasohol (or gasoline) as fuel in period t (in units per year);

XPSUG = is the export price received by Brazilian centrifugal sugar in period t (in thousands of dollars of 1980 per metric ton per year);[1]

XQETH = is the quantity of anhydrous ethanol exported in period t (in thousands of litres per year);

XQSUG = is the quantity of centrifugal sugar exported in period t (in metric tons per year);

---

[1]Nominal dollars were transformed into real dollars of 1980 using the Consumer Price Index.

and

A1, A2, A3,

B1, B2, B3, B4,

C1, C2, C3,

D1, D2, D3, D4, D5,

E1, E2, E3, E4,

F1, F2, F3,

G1, G2, G3, G4, G5,

H1, H2, H3,

J1, J2,

K1, K2, and K3 are the parameters of the model

Explanation of the Proposed Model

The Sugar Subsector

In the sugar subsector of the model, per capita domestic demand of sugar (equation 1.1) is assumed to be a function of the domestic price of sugar and of a measure of per capita income (per capita GNP). The supply of sugar (equation 1.2) is a function of the domestic and export prices, and a trend variable.

The Hydrous Ethanol Subsector

In the hydrous ethanol subsector of the model, the quantity of hydrous ethanol consumed per year (CETH 185) is in terms an exogenous variable, since it derives from the product of two exogenous variables: the volume of hydrous ethanol consumed per vehicle per year (R5), and the number of vehicles that utilize hydrous ethanol as fuel (VECETH). It should be noted, however, that this later variable is different from the stock of vehicles that utilize hydrous ethanol at the end of each period

(VEHETH). Their exact relationship is defined as:

$$VECETH_t = (VEHETH_t + VEHETH_{t-1})/2$$

The equation specified for the domestic supply of hydrous ethanol (equation 2.2) needs to be understood in the context of the National Alcohol Program (Proálcool). According to the Proálcool, the National Executive Commission on Alcohol (CENAL)[1] controls the expansion of the ethanol production by issuing permits for the installation of new ethanol distilling plants. In that capacity, the CENAL is actually able to influence the supply of ethanol, provided that producers utilize the installed capacity near the limits. Since the CENAL will issue production permits in consistency with the expected levels of ethanol consumption, the supply of ethanol must be a function of the number of vehicles that utilize straight hydrous ethanol as fuel.

It is also assumed that the chemical industry

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[1]Refer to Chapter VI for a review of its responsibilities.

utilizes only hydrous ethanol (CQUIM), and that all ethanol exports refer to the product in its anhydrous form (XQETH).

The Anhydrous Ethanol Subsector

Anhydrous ethanol is utilized in Brazil mostly as an addition to gasoline.[1] Because the proportion of anhydrous ethanol in the gasohol mixture (R1) is controlled by the government, the domestic demand for anhydrous ethanol is a fraction (R1) of the total gasohol consumption in Brazil (equation 3.1).

The supply of anhydrous ethanol (equation 3.2) suffers the same type of controls as the supply of hydrous ethanol, in terms of the government's control on the installation of new distilling plants. Therefore, the

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[1]Since 1931 the gasoline sold in Brazil has contained anhydrous ethanol in various proportions. There is no marketing differentiation between pure gasoline and the ethanol-gasoline mixture in Brazil. Therefore, in this study the ethanol-gasoline blend (sold in Brazil as "gasoline") will be referred to as gasohol.

proportion of anhydrous ethanol in the gasohol mixture (R1) is also included as an explanatory variable in the supply function.

The consumption of gasohol per year is also an endogenous variable of this model. It is indirectly estimated by the multiplication of the consumption of gasohol per vehicle and the average number of vehicles that utilize gasohol (gasoline) in each period (equation 3.7). The consumption of gasohol per vehicle is assumed to be a function of the real price of gasohol charged to consumers.

The Sugar Cane Subsector

Crucial to the entire model is the construction of the equation for the demand for sugar cane. This equation will serve as a "clearinghouse" for the supplies of sugar, hydrous ethanol, and anhydrous ethanol. It is important that a full explanation of the construction of variables R2, R3, and R4 be given.

In this study it is initially assumed that one metric ton of sugar cane yields 66 litres of anhydrous ethanol. This value is the annual average conversion rate obtained by distilling plants in the state of São Paulo,[1] and serves as an initial bench mark. Thus, the preliminary estimated value for variable R3 is:

$$R3 = \frac{1}{0.066} = 15.15152$$

There is a gain in efficiency of about 3.75 percent for the production of hydrous ethanol, relatively to the production of anhydrous ethanol. Therefore, the initially estimated value for variable R2 is:

$$R2 = \frac{1}{0.066 + (0.0375)(0.066)} = 14.60387$$

Finally, one metric ton of sugar cane yields 90

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[1]Borges, Desenvolvimento Econômico, p. 24.

kilograms of sugar and 23 kilograms of residual molasses. The residual molasses, in turn, can be transformed into 7 litres of anhydrous ethanol.[1] It is assumed that all the residual molasses are transformed into ethanol. Thus, for every ton of sugar produced there is a need to discount a portion of sugar cane which is not otherwise used directly for ethanol production. The initially estimated value for coefficient R4 is:

$$R4 = \left[\frac{1}{0.090} - \frac{0.007}{0.066} \right] = 11.00505$$

It should be noted, however, that the above results are only initial estimates for the value of variables R2, R3, and R4 in each year. The multiplication of these initial values by the respective quantities produced of sugar, hydrous ethanol, and anhydrous

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[1] Sociedade de Produtores de Açúcar e Álcool, Avaliação Econômica e Social do Proálcool (São Paulo: Sopral, 1982), p. 29.

ethanol in each year will be only close approximations of the real total quantity of sugar cane crushed in each period. That occurs because technical efficiencies vary overtime. Therefore, the initially estimated values for R2, R3, and R4 are adjusted by a <u>common</u> series of coefficients to form three time series, so that the quantity of sugar cane crushed in each year which is computed indirectly (using the quantities of sugar and ethanol produced) is equal to the real quantity of sugar cane crushed.

Finally, the equation for the supply of sugar cane (equation 4.2) includes among the explanatory variables the lagged endogenous variable ($PRODCANE_{t-1}$). The purpose of including it is to capture some of the inertia observed in the quantity of sugar cane harvested in each period. This equation also includes the price of sugar cane paid to producers by distilling plants and sugar factories lagged by two periods. Both explanatory variables are consistent with the findings of Ribeiro et al., which indicate that the most significant variables in explaining the behavior of the supply of sugar cane are trend, and the price of cane lagged by two periods.[1]

The difference between the quantity of sugar cane harvested (PRODCANE) and the quantity of sugar cane crushed (CRSCANE) in each period is used in the production of non-centrifugal sugar and liquor, and is called OTHCANE.

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[1]Refer to Chapter VIII for additional information.

CHAPTER X.

MODEL ESTIMATION

Data Used

Time series data from 1958 to 1981 were collected for almost all of the variables in the model. The sources of the data are varied, and both the data and the sources are presented in Appendix B. Time series data for a few variables were available only for the years of 1969 to 1980.

Estimation of the Parameters in the Model

The proposed theoretical model is a block-recursive system. The econometric literature is quick in pointing out that from the estimation point of view the simplest of all simultaneous-equation systems are the recursive systems. If the matrix of correlation of residuals is diagonal, and errors are not contemporaneously correlated, it follows that recursive systems should be estimated by a straightforward application of the method of ordinary least squares (OLS). Under these conditions, the use of OLS leads to consistent and asymptotically efficient estimates.[1] Also, if in addition the errors are assumed to be normally distributed, then OLS yields maximum likelihood estimates.[2]

Therefore, OLS is first used, and for each equation in the model the maximum number of observations possible was utilized to determine the better and final functional forms.[3]

However, in reality, errors may very well be contemporaneously correlated across the equations,

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[1]Jan Kmenta, Elements of Econometrics (New York: Macmillan, 1971), p. 586.

[2]J. Johnston, Econometric Methods, 2nd ed. (New York: McGraw-Hill, 1972), p. 378.

[3]Obviously, for the comparison of different functional forms of the same structural relationship a common number of observations was used.

because of the interrelationships that exist between the sugar, the ethanol, and the sugar cane economic sectors of the Brazilian economy. In this case, "using ordinary least squares would lead to consistent estimates, [which] would not be asymptotically efficient, . . . because they disregard the implied correlation between the disturbances."[1] Kmenta continues saying that "[in recursive systems] equations could be estimated by one of the system methods [three stage least squares or full information maximum likelihood], in which case the estimates would not only be consistent but also asymptotically efficient."[2]

For this reason, three stages least squares regression (3SLS) is also applied to the data in an attempt to verify whether correcting for possible

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[1]Kmenta, p. 586.
[2]Ibid.

correlated residuals across equations would result in efficiency gains.[1]

Because of the data limitations encountered for some of the variables, only the data for the years of 1969 to 1980 were used for the simultaneous estimation of the parameters in the model.

Because the number of exogenous variables is larger than the number of observations used in the simultaneous estimation, the method of principal components was used to estimate instrument variables.[2]

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[1]J. Johnston, Econometric Methods, pp. 395-398; Jan Kmenta, Elements of Econometrics, pp. 576-577; Henri Theil, Principles of Econometrics (New York: John Wiley and Sons, 1971), pp. 511-513. The method of three stages least squares was proposed by Zellner and Theil in Arnold Zellner and Henri Theil, "Three-stage, Least-squares: Simultaneous Estimation of Simultaneous Equations," Econometrica 30(1962):54-78.

[2]For a review of the method of principal components see Johnston, Econometric Methods, pp. 321-331, and 393-395; and G. S. Maddala, Econometrics (New York: McGraw-Hill, 1977), pp. 193-194. The use of principal components was first suggested by Kloek and Mennes in T. Kloek and L. B. M. Mennes, "Simultaneous Equation Estimation Based on Principal Components of Predetermined Variables," Econometrica 28(1960):45-61. The method was further developed by Amemiya in T. Amemiya, "On the Use of

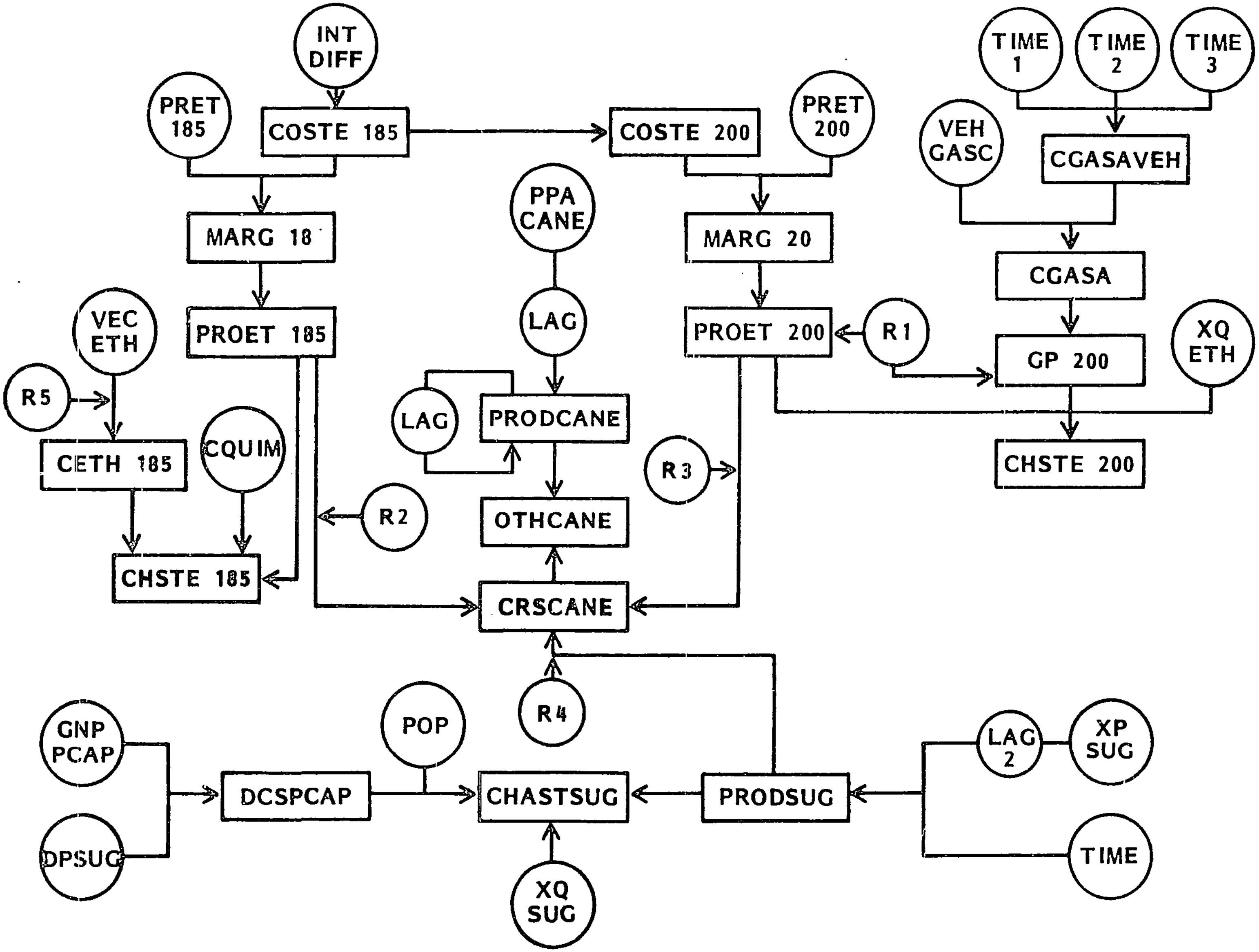
Three stages least squares parameter estimates were obtained using four and seven principal components (3SLS/4 and 3SLS/7, respectively). Two sets of principal components were used in the simultaneous estimations because there is not a great confidence in the fact that a larger number of principal components will result in a better statistical fit. Klein[1] has provided revised estimates of the Klein-Goldberger model which indicate a better statistical fit using four principal components instead of eight, using two stages least squares regression.

Parameter estimates of the final model, whose flow diagram is presented in Figure 4, are presented in Tables 13 to 19, for each estimated equation. Absolute t-values are reported in parenthesis below the regression coefficients estimated using OLS, 3SLS/4 and 3SLS/7.

Principal Components of Independent Variables in 2SLS Estimation," International Economic Review 7(1966):283-303.

[1]L. R. Klein, "Estimation of Interdependent Systems in Macroeconometrics," Econometrica 37(1969):171-192.

Figure 4. Flow diagram of the final model



INT DIFF
PRET 185
COSTE 185
COSTE 200
PRET 200
TIME 1
TIME 2
TIME 3
VEH GASC
CGASAVEH
PPA CANE
MARG 18
MARG 20
CGASA
VEC ETH
LAG
PROET 185
PROET 200
R1
GP 200
XQ ETH
R5
LAG
PRODCANE
CETH 185
CQUIM
R3
CHSTE 200
R2
OTHCANE
CHSTE 185
CRSCANE
R4
GNP PCAP
POP
LAG 2
XP SUG
DCSPCAP
CHASTSUG
PRODSUG
DPSUG
TIME
XQ SUG

TABLE 13

ESTIMATION RESULTS FOR THE PER CAPITA DEMAND FUNCTION FOR SUGAR

	OLS (n=12)	3SLS/4	3SLS/7
Estimates for:			
Intercept	0.04599 (10.10)	0.04674 (22.49)	0.04364 (28.37)
GNPPCAP	0.13641 (10.82)	0.16334 (24.68)	0.16348 (25.29)
DPSUG	-0.00084 (3.42)	-0.00100 (9.05)	-0.00084 (10.59)
MSE	7.15E-07	1.65E-07	1.41E-07
R^2	0.9333	0.9826	0.9867
DW	1.327[a]		

[a]Fails to reject the null hypothesis of no positive first-order autocorrelation at the 1 percent significance level.

TABLE 14

ESTIMATION RESULTS FOR THE SUPPLY OF SUGAR

	OLS (n=23)	OLS (n=12)	3SLS/4	3SLS/7
Estimates for:				
Intercept	-7,072,258 (8.79)	-9,603,154 (3.63)	-9,687,899 (3.14)	-7,625,917 (2.61)
TIME	224,910 (13.75)	271,505 (5.76)	281,342 (5.18)	239,054 (4.67)
$XPSUG_{t-2}$	1,402,383 (2.64)	1,089,604 (1.75)	6,145 (0.01)	969,074 (1.68)
MSE	2.29E 11	2.81E 11	3.71E 11	2.71E 11
R^2	0.9300	0.8438	0.6881	0.7992
DW	1.538[a]	1.705[a]		

[a]Fails to reject the null hypothesis of no positive first-order autocorrelation at the 1 percent significance level.

TABLE 15

ESTIMATION RESULTS FOR THE SUPPLY OF HYDROUS ETHANOL

	OLS (n=12)	3SLS/4	3SLS/7
Estimates for:			
Intercept	421,695	390,809	429,794
	(11.74)	(10.18)	(12.67)
MARG18	9,503	6,517	12,574
	(2.15)	(1.22)	(2.71)
VECETH	6.79446	7.57957	6.77141
	(11.08)	(12.94)	(14.47)
MSE	5.89E 09	7.45E 09	5.94E 09
R^2	0.9586	0.9517	0.9622
DW	1.902[a]		

[a]Fails to reject the null hypothesis of no positive first-order autocorrelation at the 1 percent significance level.

TABLE 16

ESTIMATION RESULTS FOR THE COST FUNCTION OF HYDROUS ETHANOL

	OLS (n=12)	3SLS/4	3SLS/7
Estimates for:			
Intercept	20.71532 (29.74)	20.41143 (37.33)	20.24301 (37.45)
INTDIFF	-8.73735 (4.99)	-8.65739 (6.59)	-8.15211 (6.32)
MSE	2.21285	1.22758	1.18534
R^2	0.7137	0.7800	0.7891
DW	1.177[a]		

[a]Fails to reject the null hypothesis of no positive first-order autocorrelation at the 1 percent significance level.

TABLE 17
ESTIMATION RESULTS FOR THE SUPPLY OF ANHYDROUS ETHANOL

	OLS (n=12)	3SLS/4	3SLS/7
Estimates for:			
Intercept	147,813	90,324	138,873
	(0.90)	(0.56)	(0.90)
MARG20	17,452	12,097	15,900
	(1.15)	(0.77)	(1.06)
R1	16,276,612	16,803,244	16,130,383
	(8.15)	(8.72)	(8.78)
MSE	3.73E 10	4.13E 10	4.09E 10
R^2	0.9654	0.9616	0.9636
DW	1.673[a]		

[a]Fails to reject the null hypothesis of no positive first-order autocorrelation of residuals at the 1 percent significance level.

TABLE 18

ESTIMATION RESULTS FOR THE SUPPLY OF SUGAR CANE

	OLS (n=15)	OLS (n=12)	3SLS/4	3SLS/7
Estimates for:				
Intercept	-26,175,197 (2.71)	-26,428,420 (2.08)	-24,763,969 (1.77)	-29,387,019 (2.16)
$PPACANE_{t-1}$	76,990 (2.89)	75,297 (2.27)	51,358 (1.55)	74,191 (2.34)
$PRODCANE_{t-1}$	0.91700 (11.12)	0.93050 (7.97)	1.04314 (8.71)	0.96879 (8.31)
MSE	2.69E 13	3.53E 13	4.30E 13	3.97E 13
R^2	0.9693	0.9515	0.9382	0.9434
DW	2.884[a]	2.834[a]		

[a]Durbin-Watson test statistic lies in the uncertainty region for the test of no negative first-order autocorrelation of residuals at the 1 percent significance level.

TABLE 19

ESTIMATION RESULTS FOR THE CONSUMPTION OF GASOHOL PER VEHICLE

	OLS (n=12)	3SLS/4	3SLS/7
Estimates for:			
Intercept	5.11511 (13.57)	5.24708 (11.24)	4.75234 (10.33)
TIME1	-0.03232 (4.65)	-0.03482 (4.07)	-0.02570 (3.06)
TIME2	-0.24259 (37.46)	-0.23841 (33.47)	-0.24579 (38.71)
TIME3	-0.05821 (5.99)	-0.06419 (6.29)	-0.05682 (6.20)
MSE	0.00060	0.00071	0.00062
R^2	0.9984	0.9980	0.9983
DW	2.654[a]		

[a]Durbin-Watson test statistic lies in the uncertainty region for the test of no negative first-order autocorrelation of residuals at the 1 percent significance level.

Also included are the values of the mean square error (MSE) and of the coefficient of multiple determination (R^2) for each estimated method. The Durbin-Watson "d" statistic is provided for the OLS estimations.

The Statistical Analysis System Econometric and Time Series Library (SAS/ETS) is the statistical tool utilized for the parameter estimation and simulation of the data.[1]

The final form of the model, which is graphically summarized in Figure 4, contains 18 endogenous variables and 23 predetermined variables (one lagged dependent variable). The only major difference between the specifications of the theoretical model and of the final model lies in the equation used to estimate the consumption of gasohol per vehicle (CGASAVEH). In the proposed model, CGASAVEH was assumed to be a function of the real price of gasohol paid by consumers. In the

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[1]SAS Institute Inc., <u>SAS/ETS User's Guide</u>, (Cary, NC: SAS Institute Inc., 1982).

final model, it is a function of three dummy variables: TIME1, TIME2, and TIME3.

Another difference between the proposed and the final model is the transformation of a few previously endogenous variables into exogenous ones. These variables are: the price received by distilling plants for hydrous (PRET185) and anhydrous ethanol (PRET200), and the domestic price of sugar (DPSUG). The inability to determine dependability between these three price measures and the changes in stocks of their respective products lagged by one year, indicates that the government fixes these prices in a manner which is not correlated to changes in the stocks in the previous period.[1]

Finally, in the supply of sugar cane, a better

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[1]Prices received by distillers of ethanol (hydrous and anhydrous), and the domestic price of sugar are determined by the Brazilian government. The domestic price of sugar is included as an explanatory variable in the supply of sugar as a proxy for the price received by sugar producers.

fit was obtained using the price paid for sugar cane by distilling plants and sugar factories (PPACANE) lagged by one period, instead of two periods as it was originally proposed.

Simulation Results

The most appropriate method of estimation is chosen taking into account not only the estimation efficiency measures (t-values, MSE, and R^2) presented in Tables 13 to 19. It is also important the performance of each estimation method in simulation.

Simulation performance measures are presented in Tables 36 to 52, in Appendix C, for each variable in the model. Two sets of simulation performance measures are presented in these tables: statistics of fit, and Theil's forecast error measures.

The statistics of fit presented are the root mean square error (RMSE) and the root mean square percent error (RMSPE). The root mean square error (RMSE) is a measure of the standard error of prediction, and is defined as:

$$\underline{\text{RMSE}} = \sqrt{\frac{1}{n} \sum_{t=1}^{n} (P_t - A_t)^2}$$

where:

P_t = is the predicted value;

A_t = is the actual value;

n = is the number of observations.

The root mean square percent error (RMSPE) is a measure of the percent standard error in prediction, and is defined as:

$$\text{RMSPE} = \sqrt{\frac{1}{n} \sum_{t=1}^{n} \left(\frac{P_t - A_t}{A_t}\right)^2}$$

The second set of simultaneous performance measures is Theil's forecast error measures. These statistics are commonly used to measure the ability of models to produce accurate forecasts. The first of Theil's measures presented in Tables 36 to 52 is called the relative change mean square error (RCMSE), which is defined as:

$$\text{RCMSE} = \sqrt{\frac{1}{n}\sum_{t=1}^{n}\left(\frac{P_t - A_t}{A_{t-1}}\right)^2}$$

Further decomposition of the relative change mean square error can indicate the extent to which there is a tendency to estimate too high or too low a level of the forecast variable. This measure is given by the bias proportion of RCMSE, commonly denoted as UM, and defined as:

$$\text{UM} = \frac{(\bar{p} - \bar{a})^2}{\text{RCMSE}}$$

where:

$$\bar{p} = \frac{1}{n}\sum_{t=1}^{n} p_t \quad ;$$

$$p_t = (P_t - A_{t-1})/A_{t-1} \quad ;$$

$$\bar{a} = \frac{1}{n}\sum_{t=1}^{n} a_t \quad ;$$

$$a_t = (A_t - A_{t-1})/A_{t-1} \quad ;$$

The other two components of the relative change mean square error are the regression proportion (UR), and the disturbance proportion (UD). These two decompositions of RCMSE are defined as:

$$UR = \frac{\left(S_p - r\, S_a\right)^2}{RCMSE}$$

and

$$UD = \frac{(1 - r^2)\, S_a^{\,2}}{RCMSE}$$

where:

S_p = is the standard deviation of the predicted values;

S_a = is the standard deviation of the actual values;

r = is the correlation between the predicted and the actual values.

Obviously, it follows that:

$$UM + UR + UD = 1$$

A large UM indicates that the average predicted change deviates significantly from the average actual change. A large UR indicates that the predicted values deviate significantly from the actual values. A large UD indicates that most of the relative change mean square error comes from disturbance factors. Therefore, the ideal situation (for the optimal predictor) would be one in which UM = UR = 0, and UD = 1.

The last forecast error measure presented in Tables 36 to 52 is Theil's statistic for measuring the accuracy of forecasts (U1). This statistic is defined as:

$$U1 = \frac{\sqrt{RCMSE}}{\sqrt{\sum A_t^2/n} + \sqrt{\sum P_t^2/n}}$$

The value of U1 may lie between zero and one. It is equal to zero if P_t is a perfect forecast for A_t, and it is equal to 1 if $P_t = -b\,A_t$, $(b > 0)$. Furthermore, it penalizes systematic linear bias, although it does not provide a good ranking of forecasts.[1] Ul is included among other error measures for completeness of the results presented, however, it is not going to be used as a criterium for the selection of the most appropriate estimation technique of the model.

A summary of the best estimation methods for each variable, according to the criteria discussed above is presented in Table 20. In choosing which method outperformed the others, a plain verification of higher and lower values is utilized. In other words, it is not implied that one value is <u>statistically</u> higher or lower than others. The summary of results presented in Table 20 suggests that three stages least squares with seven principal components (3SLS/7) is clearly a superior method in terms of the simulated results.

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[1]Maddala, <u>Econometrics</u>, p. 346.

TABLE 20

SUMMARY OF THE BEST ESTIMATION METHODS ACCORDING TO THE CRITERIA CONSIDERED

Variables	Estimation Meas.		Statistics of Fit		Theil's Er. Meas.	
	MSE	R^2	RMSE	RMSPE	RCMSE	U1
DCSPCAP	3SLS/7	3SLS/7	3SLS/7	3SLS/7	3SLS/7	3SLS/7
PRODSUG	3SLS/7	OLS	3SLS/7	3SLS/7	3SLS/7	. . . [a]
PROET185	OLS	3SLS/7	3SLS/7	3SLS/7	3SLS/7	. . . [a]
COSTE185	3SLS/7	3SLS/7	3SLS/7	3SLS/7	3SLS/7	3SLS/7
PROET200	OLS	OLS	OLS	OLS	OLS	. . . [a]
PRODCANE	OLS	OLS	OLS	OLS	OLS	. . . [a]
CGASAVEH	OLS	OLS	3SLS/7	3SLS/7	. . . [a]	3SLS/7
CHASTSUG	. . .	. . .	3SLS/7	3SLS/7	OLS	. . . [a]
CHSTE185	. . .	. . .	3SLS/7	OLS	OLS	. . . [a]
MARG18	. . .	. . .	3SLS/7	3SLS/4	3SLS/4	3SLS/4
GP200	. . .	. . .	3SLS/4	3SLS/7	3SLS/7	. . . [a]
CHSTE200	. . .	. . .	OLS	OLS	OLS	. . . [a]
COSTE200	. . .	. . .	3SLS/7	3SLS/7	3SLS/7	3SLS/7

MARG20	. . .	. . .	3SLS/7	3SLS/4	3SLS/4	3SLS/4
CGASA	. . .	. . .	3SLS/7	3SLS/7	3SLS/7	. . . [a]
CRSCANE	. . .	. . .	3SLS/7	3SLS/7	3SLS/7	. . . [a]
OTHCANE	. . .	. . .	OLS	OLS	OLS	. . . [a]

[a]Indicates that the criterium could not provide a ranking of the estimation methods.

Figures 5 to 15 present the actual and the simulated values, using OLS and 3SLS/7, for the endogenous variables that correspond to each one of the equations estimated in the model.

A very good performance is observed in the simulated results of all endogenous variables, exceptions made for the market-clearing variables, namely the changes in the stocks of sugar (CHASTSUG), hydrous ethanol (CHSTE185), and anhydrous ethanol (CHSTE200)--see Tables 43, 44 and 47. The statistical performance of these variables under simulation is dampened because they are very sensitive to prediction errors in the values of quantity supplied and demanded of each commodity, which is something that should be expected.

The Final Estimated Model

Because the three stages least squares estimation method with seven principal components has the better performance among the methods considered, the estimated

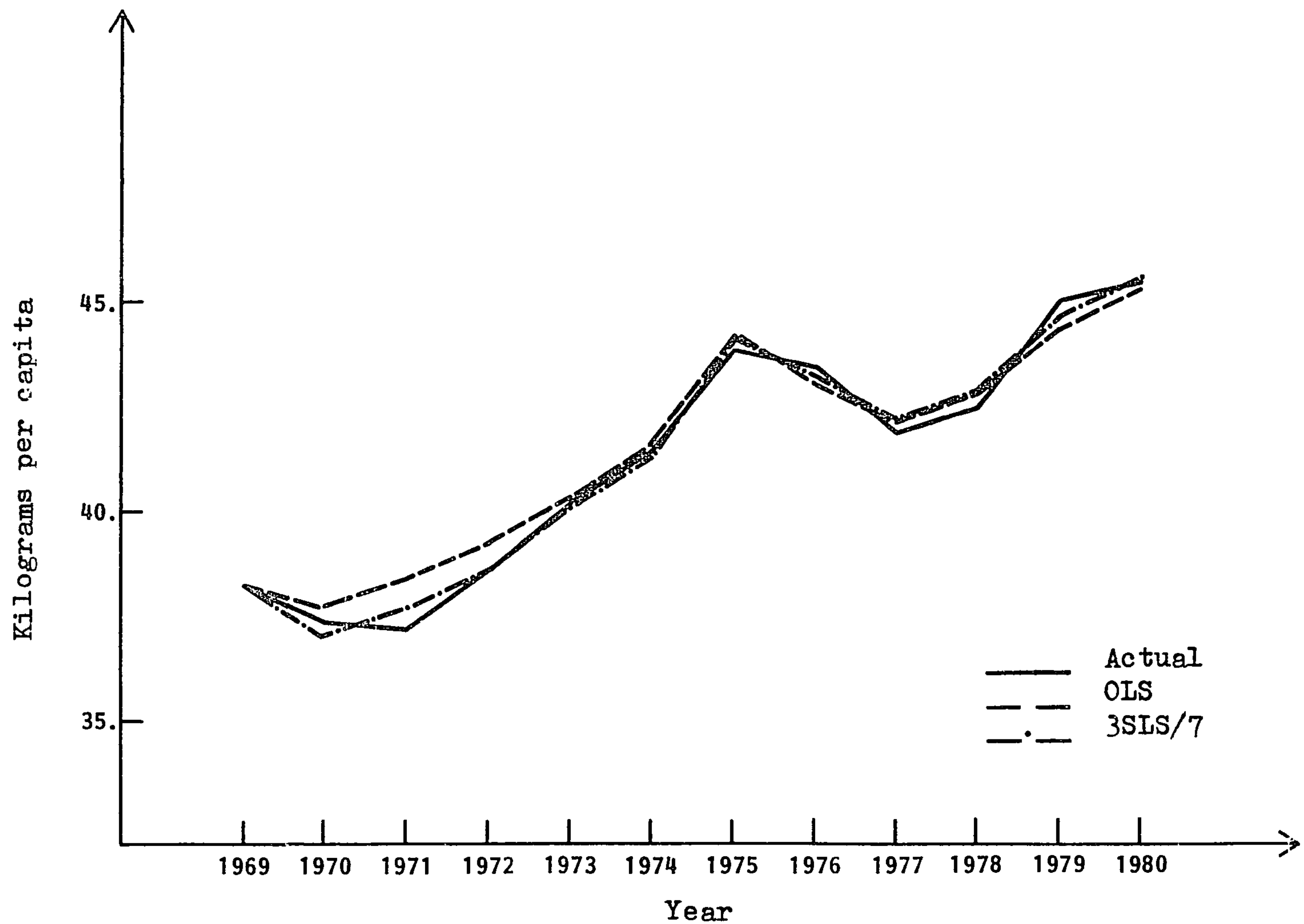

Figure 5. The per capita quantity demanded of sugar (DCSPCAP)

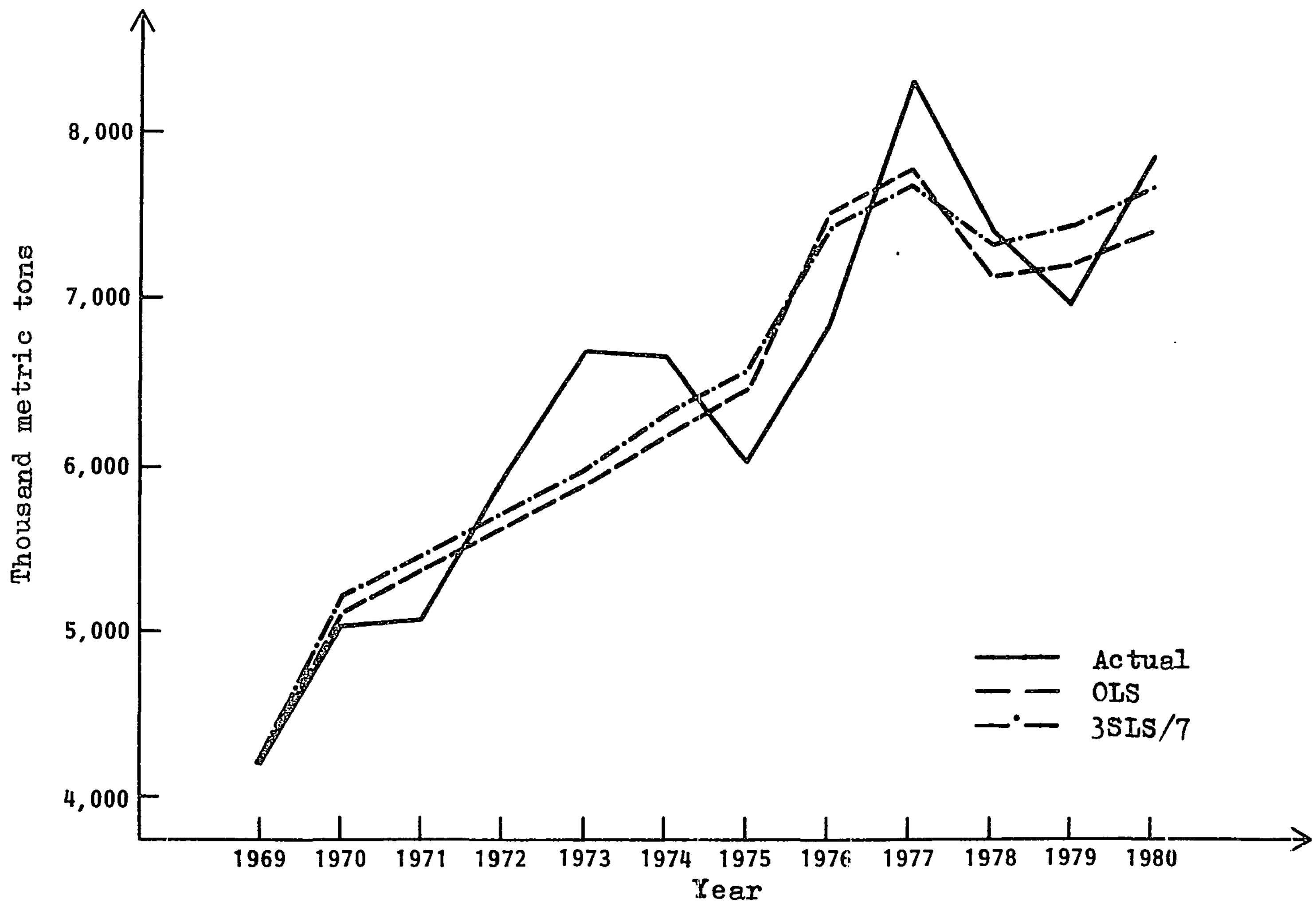

Figure 6. The quantity supplied of sugar (PRODSUG)

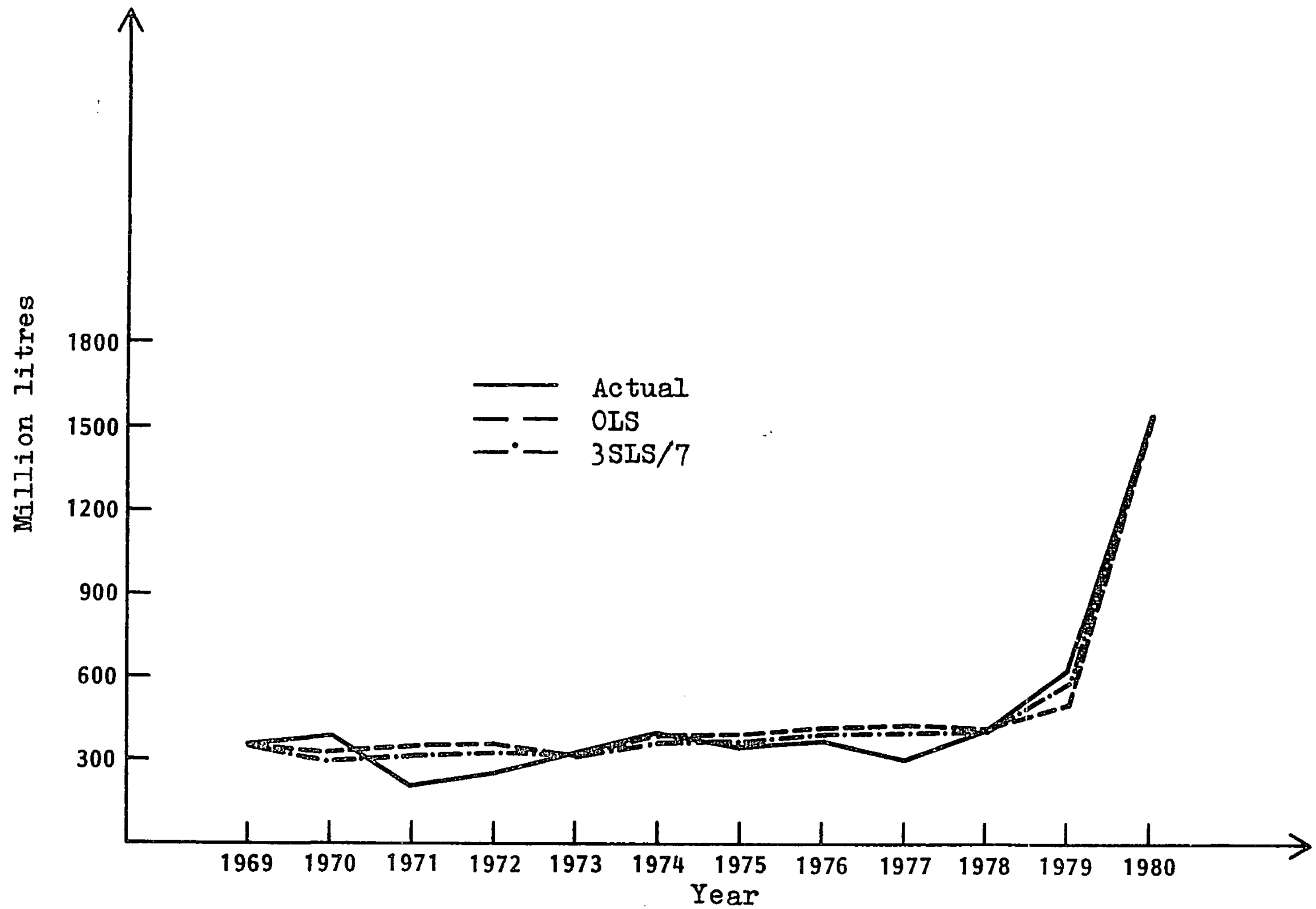

Figure 7. The quantity supplied of hydrous ethanol (PROET185)

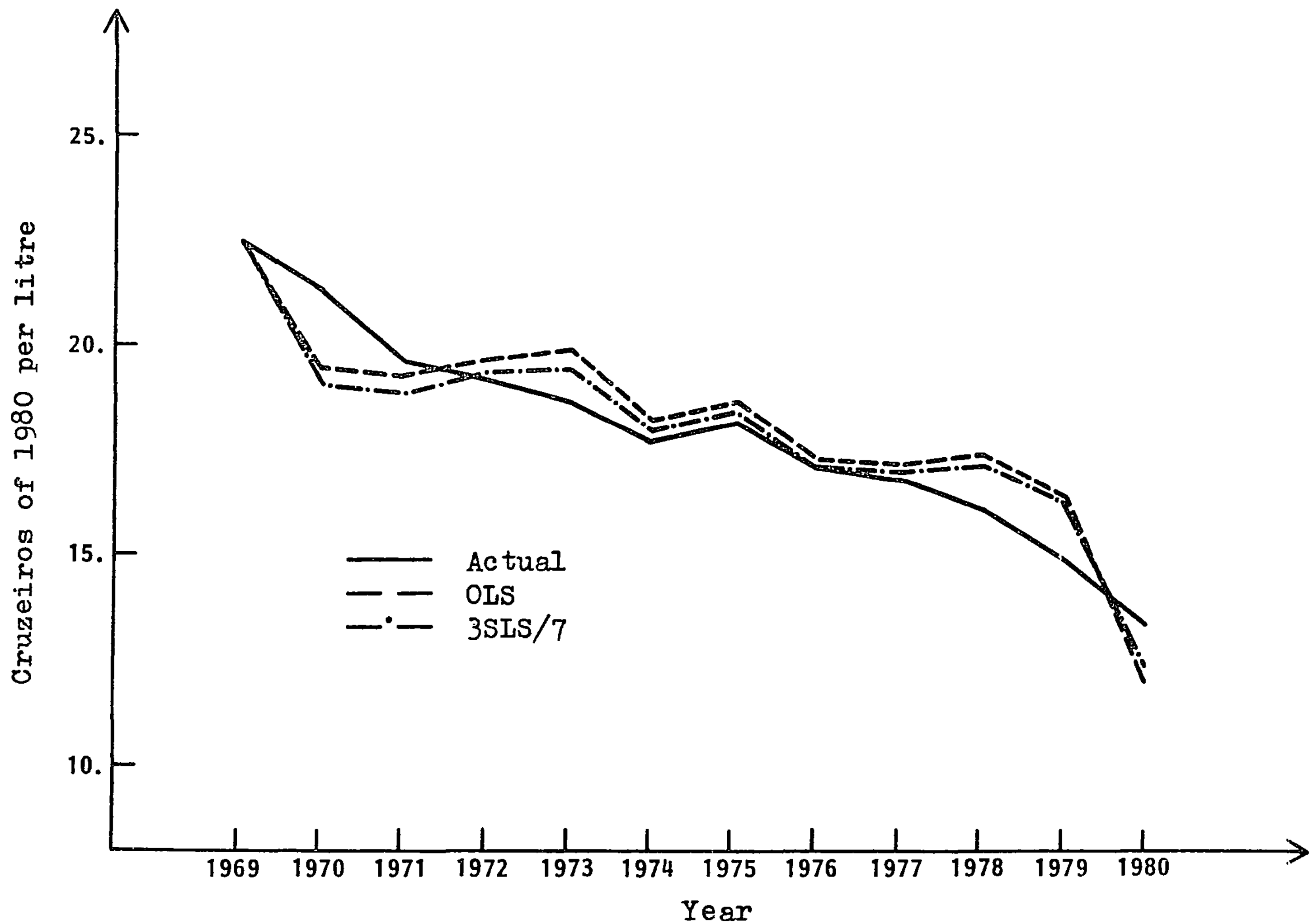

Figure 8. The cost of hydrous ethanol (COSTE185)

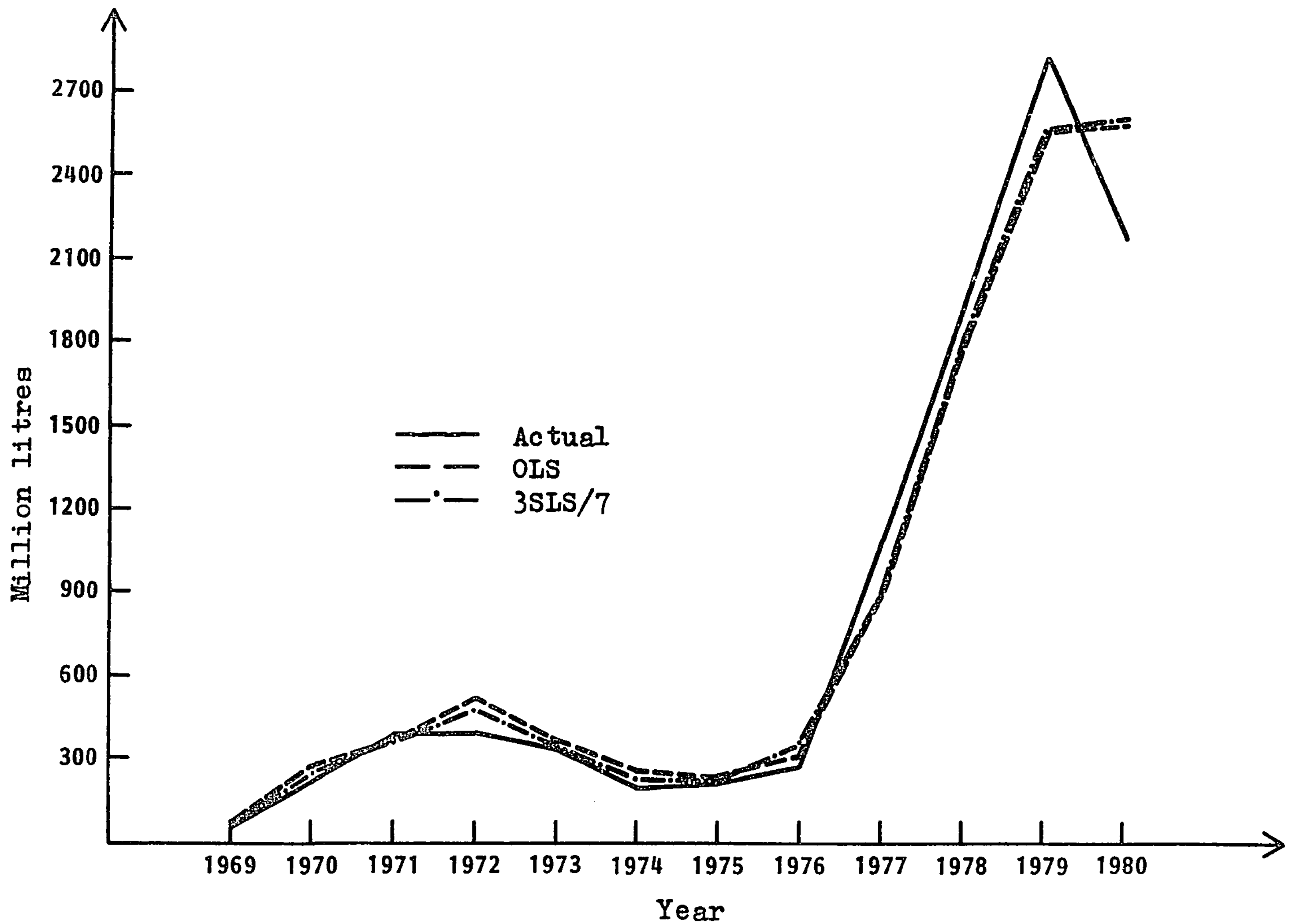

Figure 9. The quantity supplied of anhydrous ethanol (PROET200)

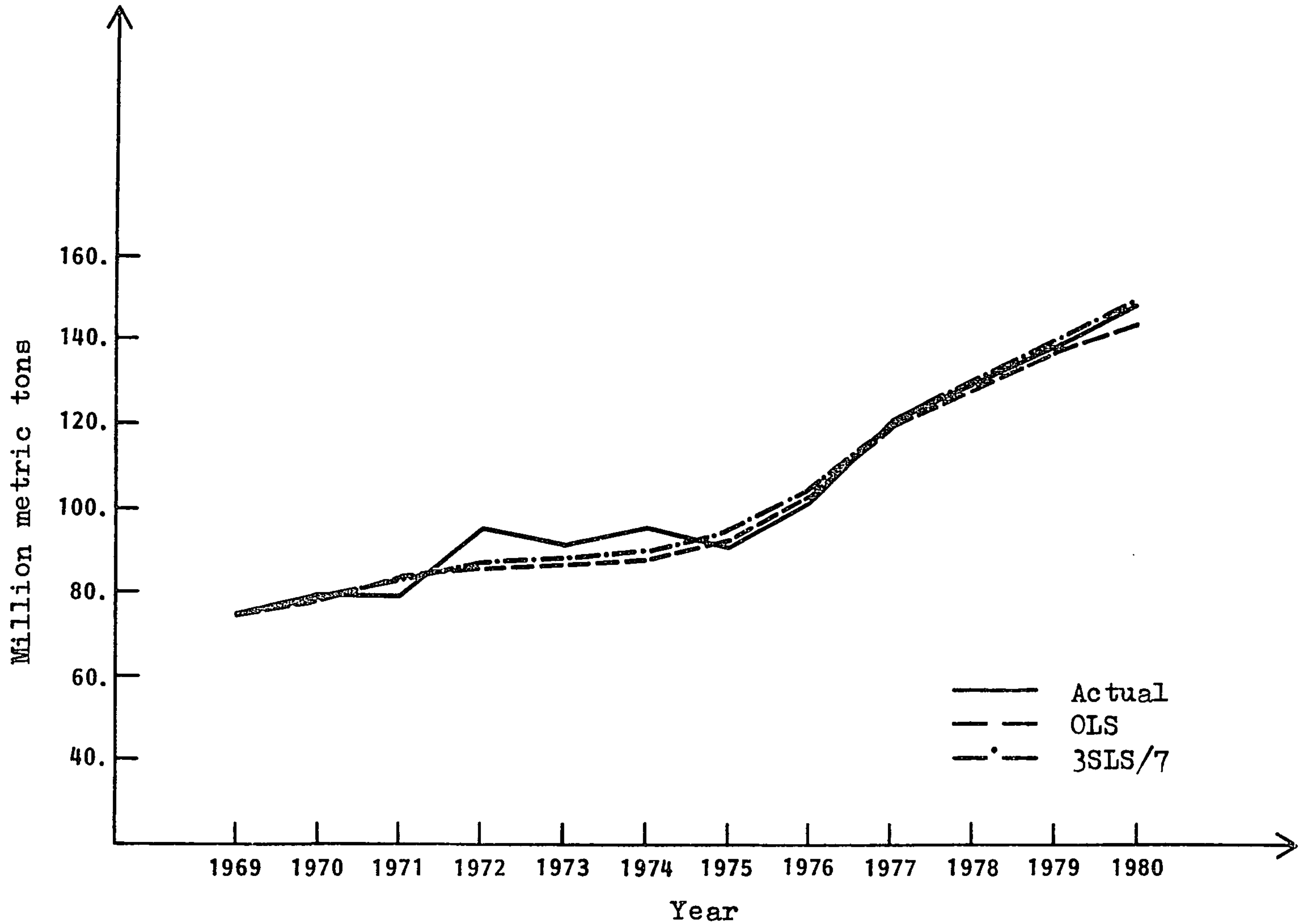

Figure 10. The quantity supplied of sugar cane (PRODCANE)

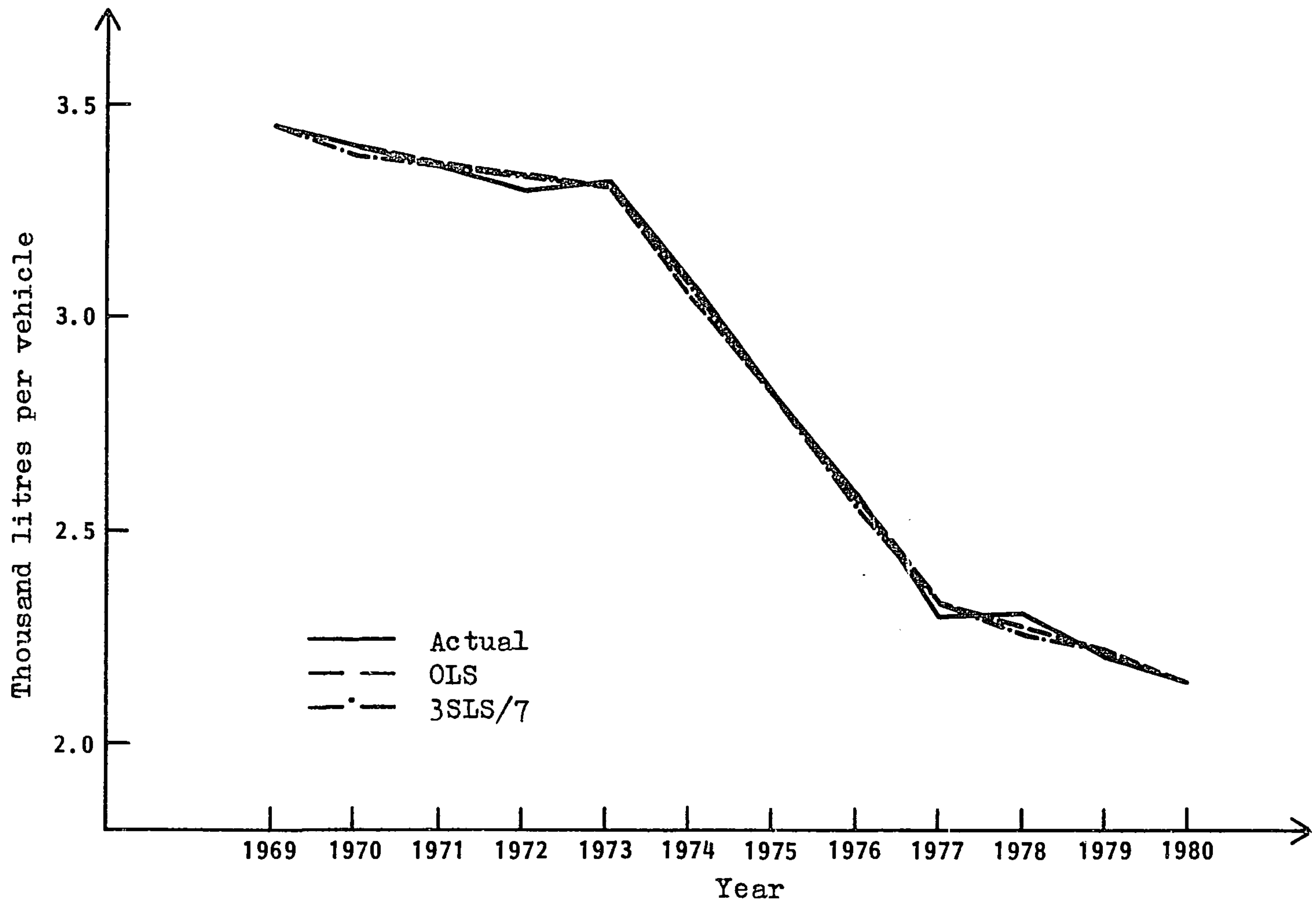

Figure 11. The consumption of gasohol per vehicle (CGASAVEH)

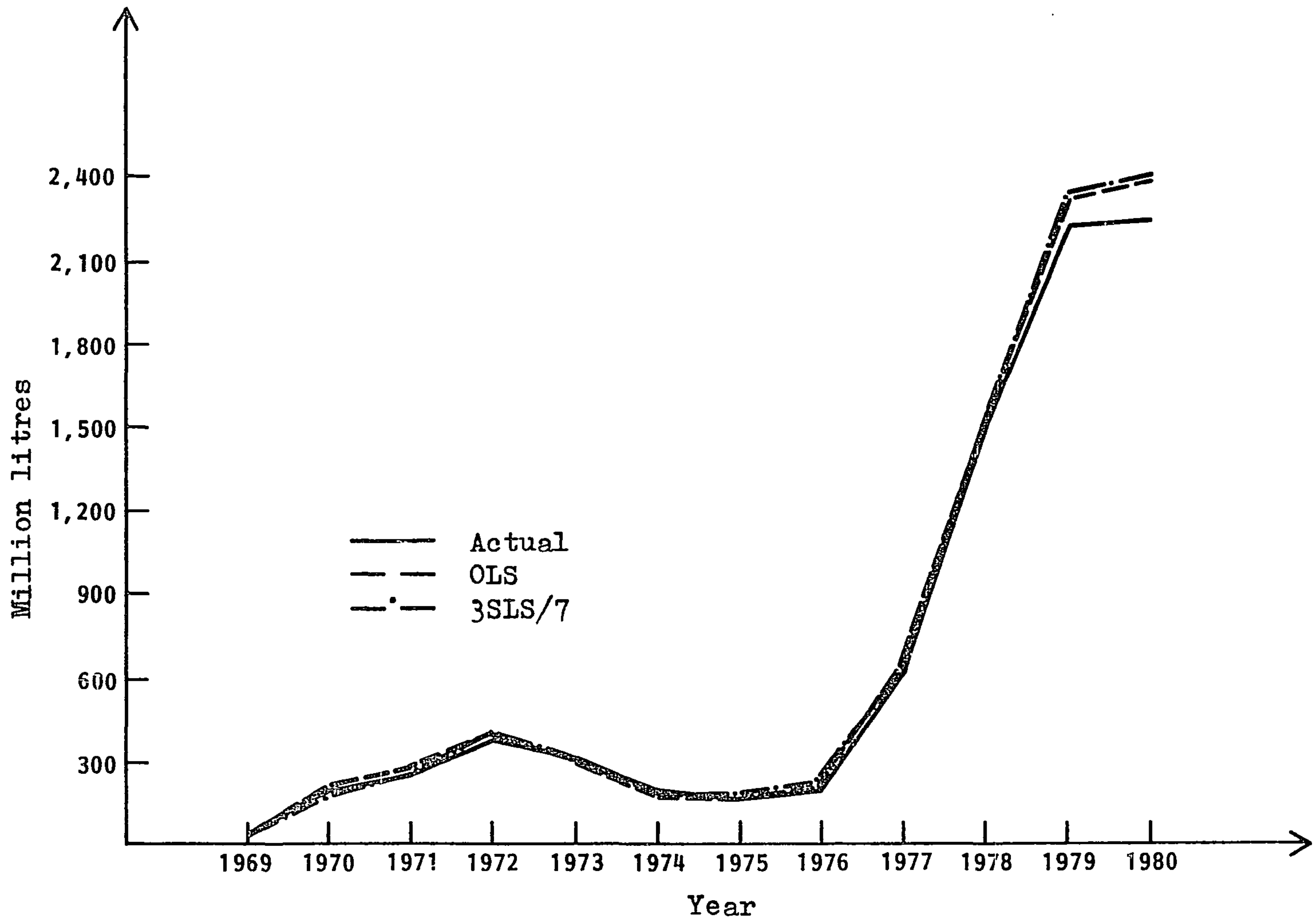

Figure 12. The quantity demanded of anhydrous ethanol (GP200)

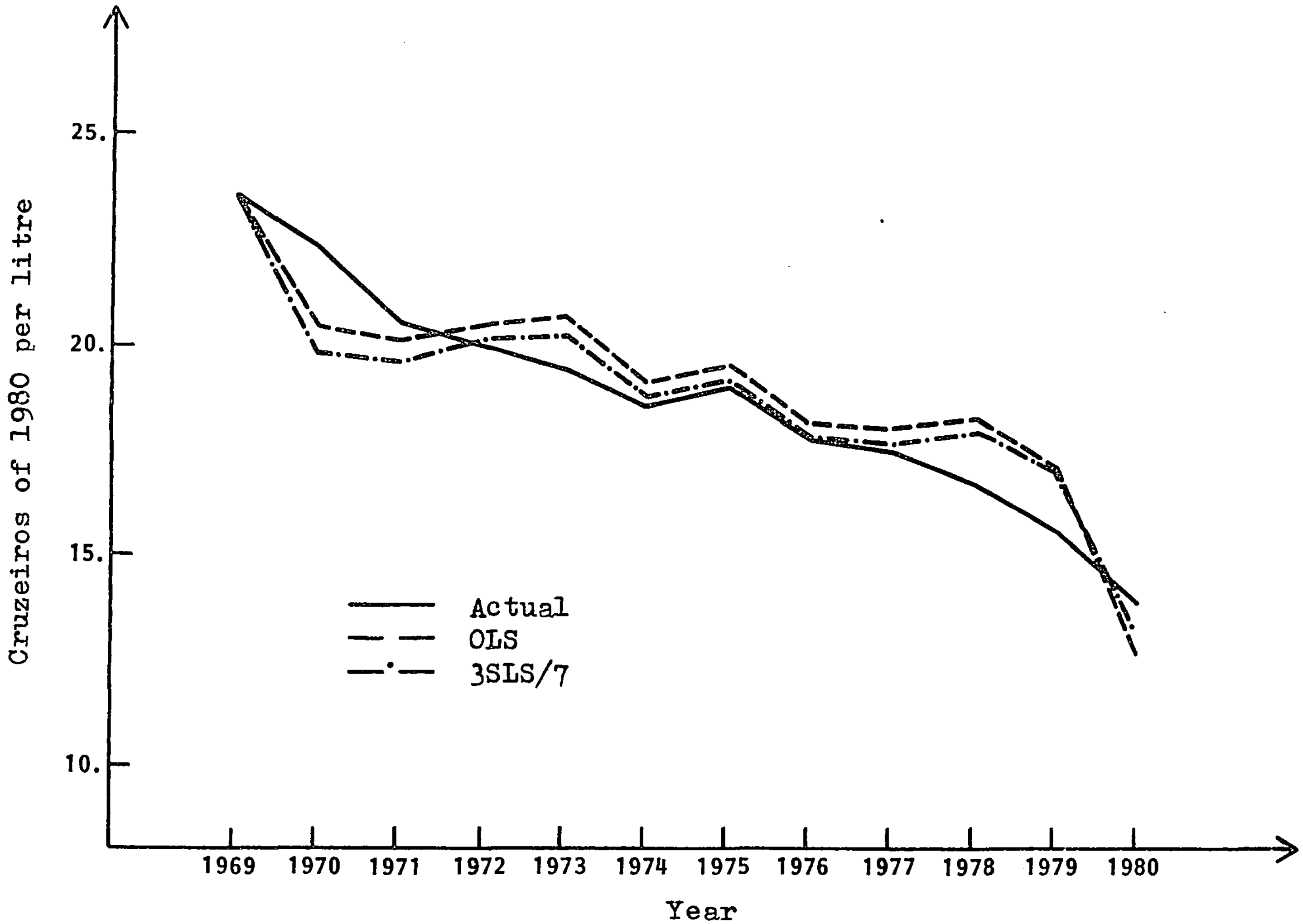

Figure 13. The cost of anhydrous ethanol (COSTE200)

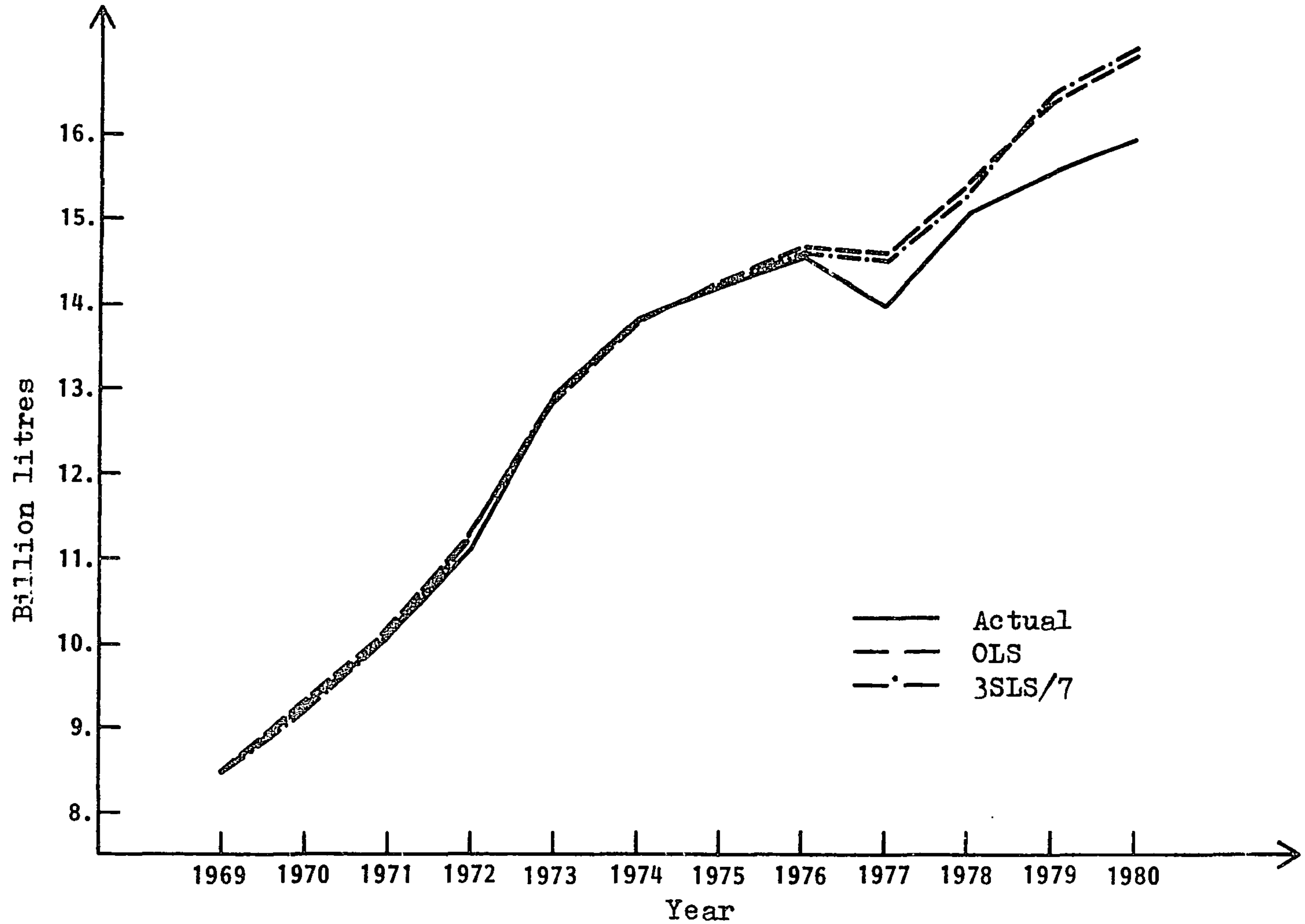

Figure 14. The total consumption of gasohol (CGASA)

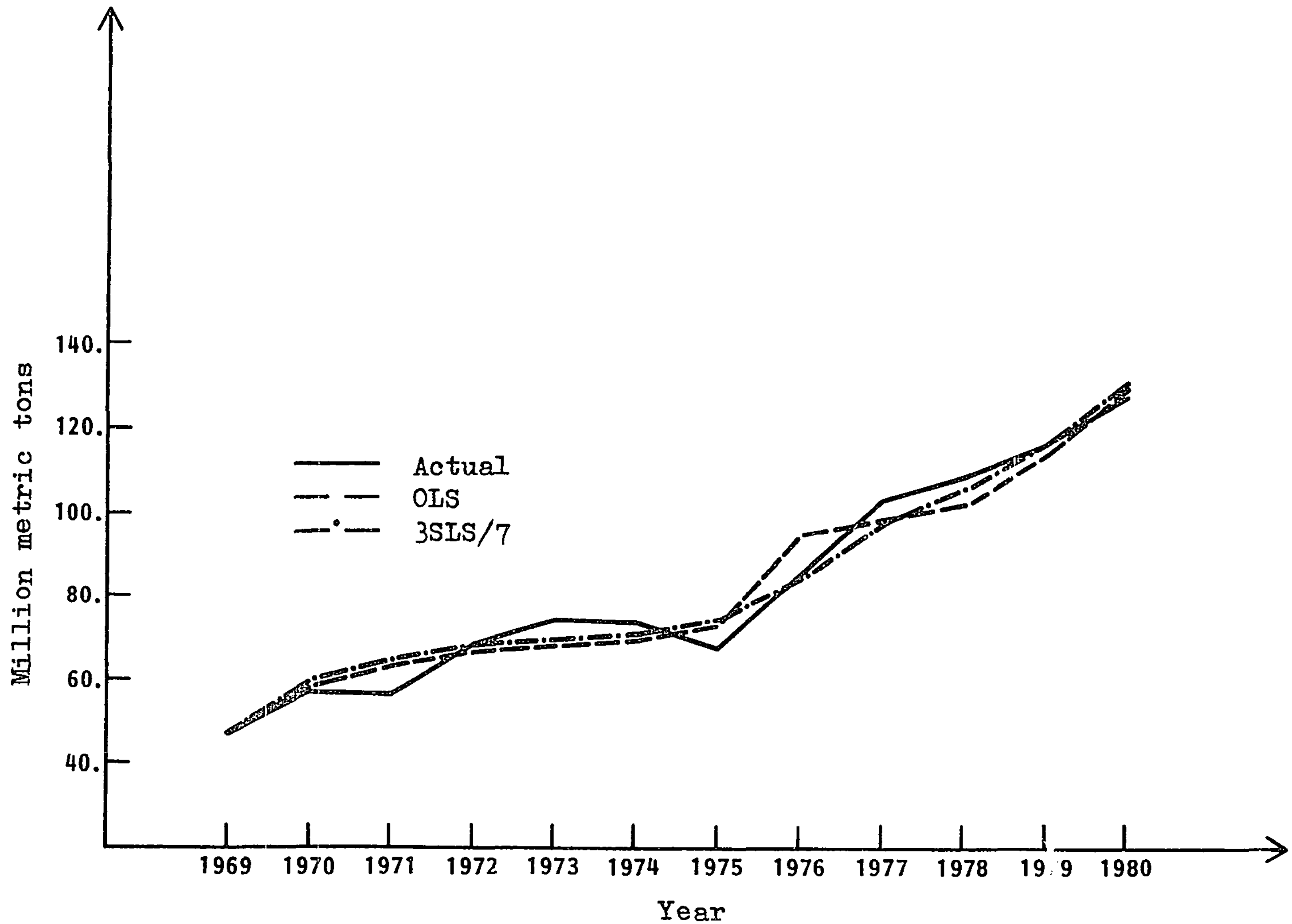

Figure 15. The quantity demanded of sugar cane (CRSCANE)

parameters using this technique are going to be utilized hereafter.

The final estimated model using 3SLS/7 is given by the following equations (absolute t-values are shown in parentheses, below the parameter estimates):

$$\widehat{DCSPCAP} = \underset{(28.37)}{0.04364} + \underset{(25.29)}{0.16348}\,(GNPPCAP) - \underset{(10.59)}{0.00084}\,(DPSUG) \qquad (1.1e)$$

$$R^2 = 0.9867$$

$$\widehat{PRODSUG} = \underset{(2.61)}{-7{,}625{,}917} + \underset{(4.67)}{239{,}054}\,(TIME) + \underset{(1.68)}{969{,}074}\,(XPSUG_{t-2}) \qquad (1.2e)$$

$$R^2 = 0.7992$$

$$\widehat{PROET185} = \underset{(12.67)}{429{,}794} + \underset{(2.71)}{12{,}574}\,(MARG18) + \underset{(14.47)}{6.77141}\,(VECETH) \qquad (2.2e)$$

$$R^2 = 0.9622$$

$$\mathrm{COST\hat{E}185} = \underset{(37.45)}{20.24301} - \underset{(6.32)}{8.15211}\ (\mathrm{INTDIFF}) \qquad (2.4e)$$

$$R^2 = 0.7891$$

$$\mathrm{PRO\hat{E}T200} = \underset{(0.90)}{138{,}873} + \underset{(1.06)}{15{,}900}\ (\mathrm{MARG20})$$

$$+ \underset{(8.78)}{16{,}130{,}383}\ (\mathrm{R1}) \qquad (3.2e)$$

$$R^2 = 0.9636$$

$$\mathrm{PRO\hat{D}CANE} = \underset{(2.16)}{-29{,}387{,}019} + \underset{(2.34)}{74{,}191}\ (\mathrm{PPACANE}_{t-1})$$

$$+ \underset{(8.31)}{0.96879}\ (\mathrm{PRODCANE}_{t-1}) \qquad (4.2e)$$

$$R^2 = 0.9434$$

$$\mathrm{CGA\hat{S}AVEH} = \underset{(10.33)}{4.75234} - \underset{(3.06)}{0.02570}\ (\mathrm{TIME1})$$

$$- \underset{(38.71)}{0.24579}\ (\mathrm{TIME2}) - \underset{(6.20)}{0.05682}\ (\mathrm{TIME3})$$

(3.8e)

$R^2 = 0.9983$

CHASTSUG = PRODSUG - (DCSPCAP)(POP) - XQSUG (1.3)

CHSTE185 = PROET185 - CETH185 - CQUIM (2.3)

MARG18 = PRET185 - COSTE185 (2.6)

GP200 = (R1)(CGASA) (3.1)

CHSTE200 = PROET200 - GP200 - XQETH (3.3)

COSTE200 = COSTE185/0.955 (3.4)[1]

MARG20 = PRET200 - COSTE200 (3.6)

CGASA = (CGASAVEH)(VEHGASC) (3.7)

CRSCANE = (R2)(PROET185) (R3)(PROET200)
(R4)(PRODSUG) (4.1)

OTHCANE = PRODCANE - CRSCANE (4.3)

A Few Words About Elasticities

The results of the above estimated model can be

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[1]The production cost of hydrous ethanol is approximately 4.5 percent inferior than the production cost of anhydrous ethanol. See Borges, Desenvolvimento Econômico, p. 21.

used to estimate a few elasticities of interest.

Barros et al.[1] estimated among other things the price elasticity of per capita demand for sugar in Brazil (0.32), and the per capita income elasticity of per capita demand for sugar in Brazil (0.53). These results were obtained using data for the years 1947 to 1973.

Using the results obtained in this study, the price elasticity of per capita demand for sugar is estimated at 0.37, and the per capita income elasticity of per capita demand for sugar is estimated at 0.31. These results are very close to the findings of Barros et al., even though in this study the data used referred to the period 1969-1980. A lower income elasticity of demand is found using the more recent data probably because sugar tends to become more income inelastic as the per capita income rises--which has been the case in

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[1]Barros et al., "Análise econométrica dos mercados interno e de exportação de açúcar."

Brazil in real terms.

Ribeiro et al.[1] estimated the short-run price (lagged by two periods) elasticity of supply of sugar cane at 1.43, using data for the years of 1947 to 1970. Using the results of the model presented above, the price (lagged by one period) elasticity of supply of sugar cane was estimated at 0.37 (data from 1969 to 1980).

Here, the range of the data may have played some role in explaining the difference between the estimated elasticities, as well as the fact that Ribeiro et al. found a significant dependency between quantity supplied and price lagged by two periods. In this study, a significant dependency was determined between quantity supplied and price lagged by one period. In both cases, the large degree of inertia observed in the supply of sugar cane may be fogging the results.

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[1] Ribeiro et al., "Relações estruturais de oferta de cana-de-açúcar."

PART III.

POLICY ANALYSIS

CHAPTER XI.

PROÁLCOOL'S OBJECTIVE FOR 1985

The Brazilian government has set a production target of 10.7 billion litres of ethanol for 1985. According to the plans,[1] 6.1 billion litres of hydrous ethanol will be consumed in 1985 by 1.7 million vehicles, 3.1 billion litres of anhydrous ethanol will be added to gasoline, and 1.5 billion litres will be used up by the chemical industry.

The government established these objectives making assumptions about the value of one endogenous and three exogenous variables contained in the model estimated in this study. The government made forecasts of the

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[1]M. Pacini, "Relatório e projeto de parecer sobre as contas do Governo--Exercício de 1979," Diário Oficial da União, 26 June 1980, pp. 12833-12848.

1985 values of the quantity of anhydrous ethanol added to gasoline (GP200, endogenous), the number of vehicles that consume hydrous ethanol (VECETH, exogenous), the average consumption of hydrous ethanol per vehicle (R5, exogenous), and the quantity of ethanol consumed by the chemical industry (CQUIM, exogenous).[1]

The objective of this chapter is to determine what should be the values of some of the policy variables included in the estimated model which would be consistent with these targets.

For this exercise, it is assumed that quantities demanded will equal quantities supplied of the three commodities in focus. This implies that there will be no change in the stocks of hydrous ethanol, anhydrous ethanol and sugar, or more simply:

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[1]Refer to Figure 4 in Chapter X.

$$CHSTE185_{1985} = 0$$

$$CHSTE200_{1985} = 0$$

$$CHASTSUG_{1985} = 0$$

The objectives of the Proálcool imply:

$GP200_{1985}$ = 3,100,000 (thousand litres)

$VECETH_{1985}$ = 1,700,000 (vehicles)

$R5_{1985}$ = 3.59 (thousand litres per vehicle)

$CQUIM_{1985}$ = 1,500,000 (thousand litres)

It is assumed that in 1985 the value of some of the exogenous variables in the model will be:

$VEHGASC_{1985}$ = 10,000,000 (vehicles)

$XQETH_{1985}$ = 300,000 (thousand litres)

$XQSUG_{1985}$ = 2,500,000 (metric tons, raw equivalent)

POP_{1985} = 134,576,000 (persons)

$GNPPCAP_{1985}$ = 0.11223[1] (in million cruzeiros of 1980 per person)

$XPSUG_{1985}$ = 0.220 (in thousands of dollars of 1980 per metric ton of sugar)

$R2_{1985}$ = 14.60387

$R3_{1985}$ = 15.15152

---

[1]Ten percent above the value of real per capita GNP in 1980.

$$R4_{1985} = 11.00505$$

The 1985 value of the dummy variables in the model will be:

$$TIME_{1985} = 68$$

$$TIME1_{1985} = 56$$

$$TIME2_{1985} = 4$$

$$TIME3_{1985} = 8$$

The 1985 Target for the Domestic Consumption of Anhydrous Ethanol

The domestic consumption of anhydrous ethanol (GP200) is estimated in the model by the following equations:

$$\hat{CGASAVEH} = 4.75234 - 0.02570 \quad (TIME1)$$

$$- 0.24579 \quad (TIME2) - 0.05682 \quad (TIME3)$$

$$\hat{CGASA} = (\hat{CGASAVEH})(VEHGASC)$$

$$\hat{GP200} = (R1)(\hat{CGASA})$$

The consumption of gasohol per vehicle (CGASAVEH) in 1985 is estimated at 1.88 thousand litres (per vehicle). As a result, the total consumption of gasohol in 1985 is estimated at 18.8 billion litres. Therefore, for the target of 3.1 billion litres of anhydrous ethanol consumed in 1985 to be achieved the government should add 16.5 percent of ethanol to gasoline in that year. This percentage level is a reasonable one, and is below the 20 percent maximum allowable to avoid engine malfunction in conventional gasoline Otto-cycle motors. Table 12 in Chapter VII shows the evolution of the percentage of anhydrous ethanol mixed to gasoline from

1939 to 1980.

In order to obtain a zero change in the stocks of anhydrous ethanol in 1985, the production of anhydrous ethanol (PROET200) must equal the sum of the quantity consumed domestically (GP20C) and the quantity exported of anhydrous ethanol (XQETH):

$$PROET200_{1985} = GP200_{1985} + XQETH_{1985} = 3,400,000$$

It follows that the profit margin on the production of anhydrous ethanol (MARG20) needed to achieve this production target is given by the following equation of the model (where R1 was estimated above at 0.164):

$$\hat{PROET200} = 138,873 + 15,900 \quad (MARG20)$$
$$+ 16,130,383 \ (R1)$$

Therefore, it is required that a profit margin of 37.71 cruzeiros of 1980 per litre of anhydrous ethanol be given in 1985 in order to achieve the production of 3.4 billion litres of anhydrous ethanol-- 3.1 billion litres for domestic use, and 0.3 billion litres for exports.

The 1985 Target for the Production of Hydrous Ethanol

According to Proálcool's objectives, in 1985 the country will produce 6.1 billion litres of hydrous ethanol to be used in vehicles that utilize straight hydrous ethanol as fuel. Moreover, the objectives include the consumption of 1.5 billion litres by the chemical industry. In this study, it is assumed that all the ethanol used up by the chemical industry is in the hydrous form. Thus, for the purposes of this model, the volume of hydrous ethanol to be produced in 1985 (PROET185) must be 7.6 billion litres (with no change in the stocks of hydrous ethanol, $CHSTE185_{1985} = 0$).

From the estimated model, the following equation for the supply of hydrous ethanol was obtained:

$$PRO\hat{E}T185 = 429{,}794 \quad + 12{,}574 \quad (MARG18)$$

$$+ 6.77141 \quad (VECETH)$$

Substituting in the above equation the target production level of hydrous ethanol in 1985 ($PROET185_{1985}$= 7,600,000) and the number of vehicles that utilize only ethanol ($VECETH_{1985}$ = 1,700,000), it can be noted that the profit margin offered to producers of hydrous ethanol should be (sic) -345 cruzeiros of 1980 per litre. This value is absurd, because the cost to produce hydrous ethanol is unlikely to be over 25 cruzeiros of 1980 per litre, in 1985. This would imply that the price paid to producers for hydrous ethanol should be negative ! The poor performance of this part of the model reflects the occasional inefficiency of economic models for long-run predictions.

The estimated value for the parameter of the explanatory variable VECETH leads to the interpretation that 6,771 litres of hydrous ethanol will be produced for every vehicle that uses straight ethanol as fuel. The value estimated for this parameter may be consistent with the observed behavior of production in the early years of the Proálcool, but it is unlikely to be as high in future years since it is expected that hydrous ethanol vehicles will consume 3,590 litres per year by 1985.

Assuming that for each vehicle that consumes hydrous ethanol there will be a target set by the Institute of Sugar and Alcohol (IAA) to produce 4,000 litres of hydrous ethanol, <u>ceterus paribus</u> the profit margin offered to producers of hydrous ethanol (MARG18) must be 29.44 cruzeiros of 1980 per litre. This value seems to be more reasonable, and in line with the estimated value of the profit margin to be offered to producers of anhydrous ethanol (MARG20) of 37.71 cruzeiros of 1980 per litre.

Since there should be some doubts over the appropiateness of this ad hoc estimation of MARG18, it seems logical to associate it to the estimated value of MARG20. Because the cost to produce hydrous ethanol is in the average 95.5 percent of the cost to produce anhydrous ethanol, it is assumed that an equivalent proportion should be given to producers in terms of the profit margins accrued with both types of ethanol.

Therefore, the final estimated value for MARG18 in 1985 is 36.01 cruzeiros of 1980 per litre of hydrous ethanol. This value would be consistent with a parameter value of 3.95142 for the explanatory variable VECETH, other things equal.

With this information in hand, estimated values for the prices paid to producers of ethanol and the level of interest subsidies can be obtained. Thus, to offer a profit margin of 36.01 cruzeiros of 1980 per litre of hydrous ethanol the following combinationsof policies

policies are possible:[1]

Policy	INTDIFF (in percent)	PRET185 (Cr$/litre)	PRET200 (Cr$/litre)
1	0.00	56.25	58.90
2	0.20	54.62	57.20
3	0.40	52.99	54.49
4	0.60	51.36	53.78

The four policy alternatives listed above form a subset of the infinite universe of possible combinations between the level of interest subsidy and the prices paid for hydrous and anhydrous ethanol. They also provide an idea of the trade-offs between incentives given for the production of hydrous and anhydrous ethanol in Brazil.

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[1]Remember that the price paid to producers of ethanol is administered by the government, as well as the level of interest subsidy.

The Supply of Sugar Cane

If the target levels of ethanol production are to be achieved, there must be enough supplies of sugar cane to provide the raw input for the production of sugar and ethanol.

To estimate the quantity supplied of sugar in 1985 the following equation of the model is utilized:

$$PRO\hat{D}SUG = -7,625,917 + 239,054 \quad (TIME) + 969,074 \; (XPSUG_{t-2})$$

The October 1983 price of sugar in New York[1] is used to estimate the quantity supplied of sugar in 1985: 8,842,951 metric tons of centrifugal sugar.

Using the estimated values of R2, R3, and R4, it is estimated that the total crushing demand for sugar cane in 1985 will be:

---

[1]220 dollars of 1980 per metric ton of sugar.

$$CRSCANE_{1985} = (R2)(PROET185_{1985}) + (R3)(PROET200) + (R4)(PRODSUG_{1985})$$

$$= (14.60387)(7,600,000) + (15.15152)(3,400,000) + (11.00505)(8,842,951)$$

$$= 259,821,701 \text{ (metric tons of sugar cane)}$$

Assuming that the production of non-centrifugal sugar and liquor will utilize 16,000,000 metric tons of sugar cane ($OTHCANE_{1985}$) in 1985, the total supply of sugar cane in 1985 must be equal to 276 million metric tons.

For this target to be achieved, the government-determined price paid for sugar cane for the years 1981 to 1984 is estimated through the equation:

$$P\hat{R}ODCANE = -24,479,970 + 65,450.53\ (PPACANE_{t-1}) + 0.9658838\ (PRODCANE_{t-1})$$

The following results are estimated:

Year (t)	$PRODCANE_t$	$PPACANE_{t-1}$	$PRODCANE_{t-1}$
1980	148,650,563	580.971	138,898,882
1981	157,400,196	585.190	148,650,563
1982	188,648,399	933.500	157,400,196
1983	218,830,532	933.500	188,648,399
1984	247,982,966	933.500	218,830,532
1985	276,140,829	933.500	247,582,966

The estimated price of sugar cane needed to achieve the production target of ethanol and maintain the present level of sugar production is significantly higher than it has been in the past. This implies that strong monetary incentives must be given to producers of sugar cane in order to achieve Proálcool's targets for 1985.

Again, these results are based on parameter estimates using data from 1969 to 1980. One should expect that lower real prices paid for competing crops in sugar cane producing regions should offset in some way the required high level for the price of sugar cane paid to producers.

The Consumption of Sugar

Finally, for the domestic consumption of sugar to be equal to 6,342,951 metric tons in 1985 (the difference between the projected supply of sugar and the estimated quantity exported), the domestic price of sugar can be estimated by:

$$DCS\hat{P}CAP = 0.04364 + 0.16348 \ (GNPPCAP) + 0.00084 \ (DPSUG)$$

Assuming that real GNP per capita in 1985 will be 10 percent above the 1980 level (or 0.11223 million cruzeiros of 1980 per capita in 1985), it follows that the domestic price of sugar in 1985 must be equal to 17.68 cruzeiros of 1980 per kilogram. This is roughly the same price observed in 1980 in Brazil.

A Note of Caution

The final results presented in this chapter should be looked upon with caution. The policy analyses produced above imply that the values of the model parameter estimates in 1985 are going to be the same as they were for the period 1969-1980. This may not be the case, and results may be affected by changes in the parameter values.

At any rate, this is still a valid exercise, and can serve as a starting point for further policy analyses that are able to utilize a more extense and up-to-date data base.

CHAPTER XII.

THE ESTIMATION OF NET INCOME ACCRUED BY PRODUCERS AND THE GOVERNMENT

The model developed in this study is suitable for the development of approximate net income measures (positive or negative) accrued by producers of sugar, by producers of ethanol, and by the government (with sugar and ethanol) during the 1970s. A series of identities is proposed to estimate these net income measures.

Producers of Hydrous and Anhydrous Ethanol

The following identities are constructed:

GRD185 = (MARG18)(CETH185)(1,000)

GRD200 = (MARG20)(GP200)(1,000)

$$SUBINTDI = (INTDIFF)(CREDETH)(1{,}000{,}000) + \sum_{i=1}^{12} SUBINTDI_{t-i}$$

$$TNRVDIST = SUBINTDI + GRD185 + GRD200$$

$$TINTSTHE = (INTRATE)(CHSTE185)(COSTE185)(1{,}000)(0.25)$$

$$TINTSTAE = (INTRATE)(CHSTE200)(COSTE200)(1{,}000)(0.25)$$

where:

GRD185 = is the total gross income accrued by all the producers of hydrous ethanol in period t (in cruzeiros of 1980 per year);

GRD200 = is the total gross income accrued by all the producers of anhydrous ethanol in period t (in cruzeiros of 1980 per year);

SUBINTDI = is the total value of government transfers to all the producers of hydrous and anhydrous ethanol in the form of subsidized interest rates charged on loans for the installation of ethanol distilling plants, in period t (in cruzeiros of 1980 per year);

TNRVDIST = is the total net income accrued by all the producers of hydrous and anhydrous ethanol in period t (in cruzeiros of 1980 per year);

CREDETH = is the total value of subsidized credit given towards the production of hydrous and anhydrous ethanol in period t under the Proálcool ("Proálcool Industrial") (in millions of cruzeiros of 1980 per year);

TINTSTHE = is the interest cost to producers of changes in the stocks of hydrous ethanol in period t (in cruzeiros of 1980 per year) assuming that stocks are held for three months;

INTRATE = is the market interest rate in period t (in percents per year);

TINTSTAE = is the interest cost to producers of changes in the stocks of anhydrous ethanol in period t (in cruzeiros of 1980 per year) assuming that stocks are held for three months;

All the other variables are defined in Chapter VIII.

Table 21 presents the values of these net income measures using the actual and the simulated data (using the 3SLS/7 parameter estimates).

The estimated total gross income measures for producers of hydrous and anhydrous ethanol--GRD185 and GRD200--include the value of taxes paid to the government by producers, and should be interpreted taking this factor in consideration.[1]

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[1]Borges has indicated that the producer of ethanol

TABLE 21

MEASURES OF THE INCOME ACCRUED BY PRODUCERS OF HYDROUS AND ANHYDROUS ETHANOL (in Billions of Cruzeiros of 1980)

Year	GRD200		GRD185		SUBINTDI		TNRVDIST		TINTDISH		TINTDISA	
	Act.	Sim.	Act.	Sim.	Act.	Sim.	Act.	Sim.	Act.	Sim.	Act.	Sim.
1974	-1.0	-1.0	0.0	0.0	0.0	0.0	-1.0	-1.0	-0.04	-0.1	-0.1	-0.02
1975	-0.7	-0.8	0.0	0.0	0.0	0.0	-0.7	-0.8	0.07	0.08	0.0	0.03
1976	-0.2	-0.2	0.0	0.0	1.0	1.0	0.7	0.7	-0.10	-0.03	0.2	0.3
1977	0.0	-0.1	0.0	0.0	4.6	4.6	4.6	4.5	-0.20	0.10	1.1	0.6
1978	-0.04	-1.8	0.0	0.0	9.6	9.6	9.5	11.4	0.05	0.09	0.9	0.4
1979	13.2	10.5	0.08	0.05	13.9	13.9	27.2	24.5	0.50	0.20	1.5	0.4
1980	14.3	17.5	1.9	2.3	31.7	31.7	47.9	51.6	2.90	2.70	-2.0	-0.6
Σ	25.5	24.0	2.0	2.4	60.7	60.7	88.3	90.8	3.20	3.00	1.6	1.1

The value of government transfers in the form of subsidized interest rates (SUBINTDI) is constructed taking into account the fact that industrial loans for the production of ethanol have a twelve-year amortization period. This is the reason behind adding the lagged values of SUBINTDI to the current value each year.

A note of caution must be attached to the values of the variables depicting the interest cost of <u>changes</u> in the stocks of ethanol--TINTSTHE and TINTSTAE. These variables do not represent the total interest cost of maintaining stocks of ethanol because they do not reflect costs of all the volume in stocks, but only of changes in the stocks. It is assumed that stocks are held for three months in the average.[1]

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receives 65 percent of the final price paid by consumers (PRET185 and PRET200), and that the government receives the remaining 35 percent. See Borges, <u>Desenvolvimento Econômico</u>, p. 3.

[1]To verify what would be the cost of changes in stocks for longer or shorter periods, adjust the factor 0.25 accordingly.

The objective of estimating the value of the variables TINTSTHE and TINTSTAE is to show that although producers may be accruing a certain positive value of net income (which includes taxes paid), part of these resources are offset by the opportunity cost of the capital they have to invest when the ethanol is not sold immediately after production.

The results presented in Table 38 show that the estimated model performs fairly well in estimating the values of the various proposed income measures.

The results indicate that producers of hydrous and anhydrous ethanol were able to accrue approximately 27.5 billion cruzeiros of 1980 in gross income during the period 1974 to 1980.[1] Since the creation of the Proálcool this value is 29.5 billion cruzeiros (period of 1976 to 1980).

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[1]This value includes taxes paid by producers of ethanol.

The results also show that a massive amount of wealth was transferred in terms of subsidized credits to ethanol producers. From 1976 until 1980, this value reached 61 billion cruzeiros of 1980 (SUBINTDI).

The estimated values for the variables that measure the interest cost of changes in stocks held by producers (TINTDISH and TINTDISA) indicate that producers have beared some net losses over the period of 1974 to 1980. During this period, producers of ethanol have had the interest costs on stocks increased by 4.8 billion cruzeiros (3.2 plus 1.6). These results suggest that a better job of coordinating the production of ethanol could still be done in Brazil, and that imperfect production plans have led to unnecessary costs been inflicted upon the ethanol sector.

Producers of Sugar

The following identities are proposed:

GRREF = (DPSUG)((DCSPCAP)(POP) + XQSUG)(1,000)

- (COSTSUG/60)(PRODSUG)(1,000)

SUBINTRE = (INTDIFF)(CREDREF)(1,000)

CREDREF = (CREDCOO)/(0.60)

TNRVREF = GRREF + SUBINTRE

TINTSTRE = (INTRATE)(CHASTSUG)(COSTSUG/0.60)(1,000)

(0.25)

where:

GRREF = is the total gross income accrued by all the sugar producers in period t (in cruzeiros of 1980 per year). This is an approximated measure since taxes on the sale of sugar are included in the domestic price of sugar (DPSUG);

COSTSUG = is the cost of producing raw centrifugal sugar in period t (in cruzeiros of 1980 per bag of 60 kilograms per year);

SUBINTRE = is the value of transfers from the government to all the producers of sugar in the form of subsidized interest rates (in cruzeiros of 1980 per year);

CREDREF = is the estimated value of subsidized credit given for the production of sugar. It is estimated from the value of the credit given to cooperatives of sugar producers (CREDCOO), which account for approximately 60 percent of Brazil's production of sugar (in cruzeiros of 1980 per year);

TNRVREF = is the total net income accrued by all the producers of sugar (in cruzeiros of 1980 per year);

TINTSTRE = is the interest cost to producers of <u>changes</u> in the stocks of sugar, assuming that stocks are held for three months (in cruzeiros of 1980 per year).

One of the assumptions made in the construction of these identities is that sugar producers receive the same price for sugar sold in the domestic market and for sugar sold to be exported. This assumption is not very far off, since the Brazilian government is the only body that actually exports sugar, which it buys from producers at regulated prices.

Another assumption is that the total subsidized credit received by sugar producers is in proportion to the credit received by cooperatives of sugar producers. These cooperatives account for approximately 60 percent of Brazil's production of sugar.[1] It is assumed that most of the credit given by the government to sugar producers is for marketing purposes, and is repaid in one

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[1]Copersucar, 40 percent; others, 20 percent.

year. This assumption takes into account that no significant additions to the sugar production capacity have occurred in the period considered.

It is assumed that sugar producers maintain their final product in stocks for three months in the average.

Estimated values for these income measures are presented in Table 22, using the actual and the simulated data (3SLS/7). A good performance of the model is observed by comparing the results obtained using the actual data with the results obtained using simulated values.

The results indicate that producers of sugar have been able to increase their gross income from the sale of sugar (GRREF) from 1976 to 1980. The values presented for the variable GRREF must be looked upon with caution since the direct taxes collected from the sale of sugar (approximately a percentage of the price) are included in the results. In spite of this fact, there is no doubt that since the creation of the Proálcool the gross income accrued by sugar producers has increased.

TABLE 22

MEASURES OF THE INCOME ACCRUED BY PRODUCERS OF SUGAR

(in Billions of Cruzeiros of 1980)

Year	GRREF		SUBINTRE		TNRVREF		TINTSTRE	
	Act.	Sim.	Act.	Sim.	Act.	Sim.	Act.	Sim.
1974	41.8	46.0	0.06	0.06	41.9	46.6	0.06	-0.3
1975	20.6	13.5	0.30	0.30	20.9	13.8	-0.40	0.2
1976	24.1	16.1	0.50	0.50	24.6	16.6	1.60	2.7
1977	44.9	52.1	0.60	0.60	45.5	52.7	1.90	1.0
1978	46.3	49.0	0.50	0.50	46.8	49.5	1.10	0.8
1979	54.0	48.3	0.80	0.80	54.8	49.1	-0.20	0.9
1980	63.7	65.6	1.20	1.20	65.0	66.8	-0.60	-1.3
Σ	295.4	290.6	4.00	4.00	299.4	294.6	3.50	4.0

The value of government transfers in the form of subsidized credit is small relatively to the other figures in Table 39. From 1974 until 1980, this variable added to 4 billion cruzeiros of 1980.

The observed results also indicate that sugar producers have had to bear increased storage costs, which are reflected by the positive values of the variable TINTSTRE. This variable shows, however, only the cost of changes in the stocks of sugar.[1]

The Government

The following identities are constructed:

$$GRVSE185 = (CETH185)(1{,}000)(PPET185 - PRET185)$$

$$GRVSGASA = (CGASA)(1{,}000)(PPGAS - COSTGAS(1 - R1) - (R1)(PRET200))$$

[1]Results are based on the assumption that stocks are held for three months in the average.

GRVXSUG = (XQSUG)(1,000)((XPSUGN)(EXCHRATE)/(X)

- DPSUG)

TGRV = GRVSE185 + GRVSGASA + GRVXSUG

CREDTOT = SUBINTDI + SUBINTRE

SAVPROA = (CGASA)(1,000)(R1)(COSTGAS - COSTE200)

+ (CETH185)((COSTGAS)/(1.1) - COSTE185)

SAVPROA1 = (CGASA)(1,000)(R1)((COSTGAS)(1.9)

- COSTE200) + (CETH185)((COSTGAS)(1.9)/(1.1)

- COSTE185)

where:

GRVSE185 = is the government's gross income from the sale of hydrous ethanol in period t (in cruzeiros of 1980 per year);

PPET185 = is the price paid by consumers for hydrous ethanol in period t (in cruzeiros of 1980 per litre per year);

GRVSGASA = is the government's gross income from the sale of gasohol in period t (in cruzeiros of 1980 per year);

COSTGAS = is the cost of gasoline in period t (in cruzeiros of 1980 per litre per year);

GRVXSUG = is the government's income from the exports of sugar in period t (in cruzeiros of 1980 per year);

XPSUGN = is the export price of sugar, unadjusted for inflation in period t (in dollars of 1980 per kilogram per year);

EXCHRATE = is the average exchange rate between the U.S. dollar and the Brazilian cruzeiro (free rate) in period t (in cruzeiros per dollar per year);

X = is the variable used for deflating nominal

TGRV = is the government's total income from the sale of hydrous ethanol and gasohol, and the exports of sugar in period t (in cruzeiros of 1980 per year);

CREDTOT = is the total amount of transfers from the government to producers of sugar and ethanol, in the form of subsidized credits in period t (in cruzeiros of 1980 per year);

SAVPROA = is the amount of savings accrued by the nation from the use of hydrous and anhydrous ethanol in substitution to gasoline in period t (in cruzeiros of 1980 per year), assuming that the imported oil is paid without further financial costs;

SAVPROA1 = is the same as SAPROA, but assumes that imported oil is paid with costly borrowed funds--foreign debt--in period t (in cruzeiros of 1980 per year).

Fuel distribution costs are not deducted from the government's income from the sale of hydrous ethanol and gasohol--GRVSE185 and GRVSGASA, respectively.

In consistency with the identities presented in the previous section, it is assumed that the government pays the domestic price of sugar to producers, for all the sugar exported from Brazil.

Two measures are proposed for the nation's savings from the use of ethanol in substitution to gasoline: SAVPROA and SAVPROA1. In both measures, it is assumed that hydrous ethanol has substituted gasoline with a loss of 10 percent in consumption efficiency. This is equivalent to saying that one litre of gasoline is substituted in consumption by 1.1 litres of hydrous ethanol in the average (considering all vehicles).

One of the measures of the net savings with the Proálcool, SAVPROA, assumes that the oil that would have been imported if the Proálcool had not been implemented would have been paid without other financial costs. The other measure, SAVPROA1, assumes that oil would have been paid with funds loaned abroad at a 9 percent real rate of interest[1] for 10 years. This second measure is relevant because Brazil's oil imports have been paid since 1974 through the acquisition of foreign debt. Since the real rates of interest charged on these loans are so high, the actual cost of importing oil is a multiple of its original cash price.

The estimated values of these income measures are presented in Table 23, using the actual and the simulated data (3SLS/7).

The results indicate that the government has sold hydrous ethanol to consumers at less than the price it paid producers, during the period considered. This is verified by the fact that the estimated values for variable GRVSE185 add up to minus 200 million cruzeiros of 1980, during the years of 1979 and 1980. This observation is consistent with the government's objective

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[1]The sum of the prime rate and the "spread Brazil", minus the inflation of U.S. dollars.

TABLE 23

MEASURES OF THE INCOME ACCRUED BY THE GOVERNMENT--WITH SUGAR AND ETHANOL (in Billions of Cruzeiros of 1980)

Year	GRVSE185		GRVSGASA		GRVXSUG		TGRV		CREDTOT		SAVPROA		SAVPROA1	
	Act.	Sim.	Act.	Sim.	Act.	Sim.	Act.	Sim.	Act.	Sim.	Act.	Sim.	Act.	Sim.
1974	0.0	0.0	193	192	60	60	250	249	3	3	-2	-2	-1	-1
1975	0.0	0.0	220	220	52	52	268	268	4	4	-2	-2	-1	-1
1976	0.0	0.0	263	265	-0.5	-0.5	254	256	9	9	-2	-2	-1	-1
1977	0.0	0.0	272	283	-19	-19	242	253	12	12	-7	-7	-3	-4
1978	0.0	0.0	263	269	-18	-18	232	238	17	17	-16	-18	-8	-10
1979	-0.09	-0.09	192	203	-13	-13	164	174	24	24	-17	-21	-2	-5
1980	-0.10	-0.10	324	345	23	23	302	323	58	58	-3	-1	22	25
Σ	-0.2	-0.2	1,727	1,777	84.5	84.5	1,712	1,761	127	127	-49	-49	6	3

of estimulating the production and the consumption of ethanol in Brazil.

However, the total value of the price subsidy given to the production and consumption of hydrous ethanol is minimal in comparison with the estimated gross income from the sale of gasohol accrued by the government (GRVSGASA).[1] The results indicate that the government received a net income of 1,727 billion cruzeiros of 1980 from 1974 to 1980 from the sale of gasohol.

The results also indicate that from 1976 to 1979 the government-determined domestic price of sugar has been larger than the export price (as the value of GRVXSUG is negative in these years). The domestic price was lower than the international price in 1974, 1975, and 1980. Indeed, looking at the evolution of both prices

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[1] These values were not deducted for the distribution and marketing costs of fuels, and should be interpreted taking this fact into account.

(domestic and export price of sugar), it can be observed that the IAA has been very effective in isolating Brazil's sugar industry from fluctuations of the international market.

The results also indicate that the savings accrued by the nation for using ethanol in substitution to gasoline, even without considering the multiplicative effect upon the economy of the jobs created with the production of ethanol,[1] have summed up to 5 billion cruzeiros of 1980 (SAVPROAl), from the moment of creation of the Proálcool in 1976 until 1980.[2]

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[1]According to the World Bank, for each million litre of ethanol produced in Brazil there are 32 new direct jobs created (7 in the industrial sector, and 25 in the agricultural sector), besides other indirect jobs that are created in the sectors of construction, machinery and equipment, and assembly. See Sociedade de Produtores de Açúcar e Álcool, Avaliação Econômica e Social do Proálcool (São Paulo: SOPRAL, 1982), p. 8; and Cooperativa Central dos Produtores de Açúcar e Álcool do Estado de São Paulo, Aspectos Econômicos da Produção de Cana, Açúcar e Álcool, Período 1978/1980 (São Paulo: COPERSUCAR, 1980), p. 55.

[2]Taking into consideration the savings in financial costs.

Moreover, after the second big rise in the price of oil in 1979, the savings accrued with the Proálcool have been largely positive, if the financial costs of borrowed funds are considered (SAVPROA1), and close to breaking even if financial costs are not considered (SAVPROA).[1] The results of this study suggest that savings of approximately 22 billion cruzeiros of 1980 per year will be accrued during the 1980s, if the price of petroleum is maintained at 28.67 dollars of 1980 per barrel.

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[1]The estimated cost of gasoline utilizes the price of petroleum F.O.B. at Ras Tanura in Saudi Arabia. If one would add to the price of oil the cost of freight and insurance from Saudi Arabia to Brazil, the estimated savings with the Proálcool would be considerably larger. In this study the price of oil F.O.B. Ras Tanura was used because the author did not have data on the actual cost of oil F.O.B. Brazil. Also, the price of oil charged by Saudi Arabia is in general lower than the price charged by other oil producing countries.

CHAPTER XIII.

FINAL REMARKS

Since the start of the Portuguese occupation of Brazil, the cultivation of sugar cane has fostered the economic development of Brazil. During the entire colonial period (1500-1822), the production of sugar from sugar cane was by far the most important economic activity. Until 1830 sugar was the product with the largest share of the total value of exports from Brazil. Although after this date sugar lost its prominence in Brazil's export list, it continued to be a significant source of export revenues through today.

It is not an exaggeration to say that the cultivation of sugar cane in Brazil influenced its ethnic composition, and, for once, its geographical limits.[1]

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[1]Read about the Dutch invasion of the northeastern coast of Brazil in Chapter IV.

Sugar Cane and the Energy Problem

The rise in the price of petroleum during the 1970s[1] put an end to a long period of cheap and abundant energy supplies. It also raised the possibility of expanding the role of the sugar cane culture in the Brazilian economy through the production of ethanol from sugar cane. The economy of Brazil was specially vulnerable to the rise in oil prices because of its limited domestic production of petroleum, and its dependency on oil imports. Brazil's known reserves of petroleum amount to only 1.4 billion barrels, which would be sufficient for its domestic consumption for four years.[2]

Although there are no indications of an iminent scarcity of petroleum in the short and medium runs, the

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[1] And most notably in 1973 and 1979.

[2] Sociedade de Produtores de Açúcar e Álcool, Avaliação Econômica e Social do Proálcool, p. 22.

available data suggests that oil-derived fuels will be gradually substituted as oil prices increase due to limited supplies.[1] The world's reserves of petroleum were estimated at 620 billion barrels in 1982, posing a definite ceiling to the present levels of consumption which are around 23 billion barrels per year.[2]

The National Alcohol Program

Robert McNamara was quoted for saying once that "the most expensive form of energy is that one we do not

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[1]Read the section about the size of the world's reserves of petroleum in Appendix A.

[2]It is a fallacy to think that oil would be consumed to its last drop. As the relative abundance of oil decreases, its price will increase to a point in which it will become sufficiently scarce and expensive to be substituted by other sources of energy. Also, as oil prices increase, the prospection of oil in more remote areas of the globe may become feasible, opening the door for new discoveries. Indeed, many hopes lie in the potential of areas such as Antartica, Siberia, and the Barentz and Kara seas to become the dominant oil-producing regions of the future.

own."[1] Brazil has followed it to the letter. The response given by the Brazilian nation to its handicap in terms of limited oil reserves has been the creation of a National Alcohol Program.[2] This program was established in November of 1975 with the objectives of increasing the production and consumption of ethanol in substitution to gasoline, and of providing an alternative use for the sugar cane produced in Brazil, thus contributing to the stabilization of the sugar market.

Before 1975, ethanol was produced in Brazil after all the markets for residual molasses, its main raw input, were exhausted.[3] Under the Proálcool, the

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[1]Sociedade de Produtores de Açúcar e Álcool, Avaliação Econômica e Social do Proálcool, p. 32.

[2]A history of the creation of the National Alcohol Program (Proálcool) is presented in Chapter VII.

[3]Exception made for the ethanol produced as liquor (called aguardente) which uses sugar cane directly as an input.

residual molasses obtained as a by-product of the industrialization of sugar would not be available in the needed amounts to reach the target levels of ethanol production. Thus, ethanol started being produced directly from sugar cane, in addition to residual molasses.

Sugar cane was the natural choice of raw material for the production of ethanol because of its efficiency in terms of ethanol obtained for each hectare planted--4,620 litres per hectare[1] in Brazil--and because of the economic advantages of sugar cane over other crops.[2] Moreover, most of the territory of Brazil is suitable for the cultivation of sugar cane, exceptions made for the desertic areas in the northeast, the swamps in the west-central area, and other mountainous regions. Figure 16 provides a bird's-eye view of the areas in Brazil that

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[1]See Table 9 in Chapter VI.

[2]The Proálcool included also the production of ethanol from cassava and potatoes.

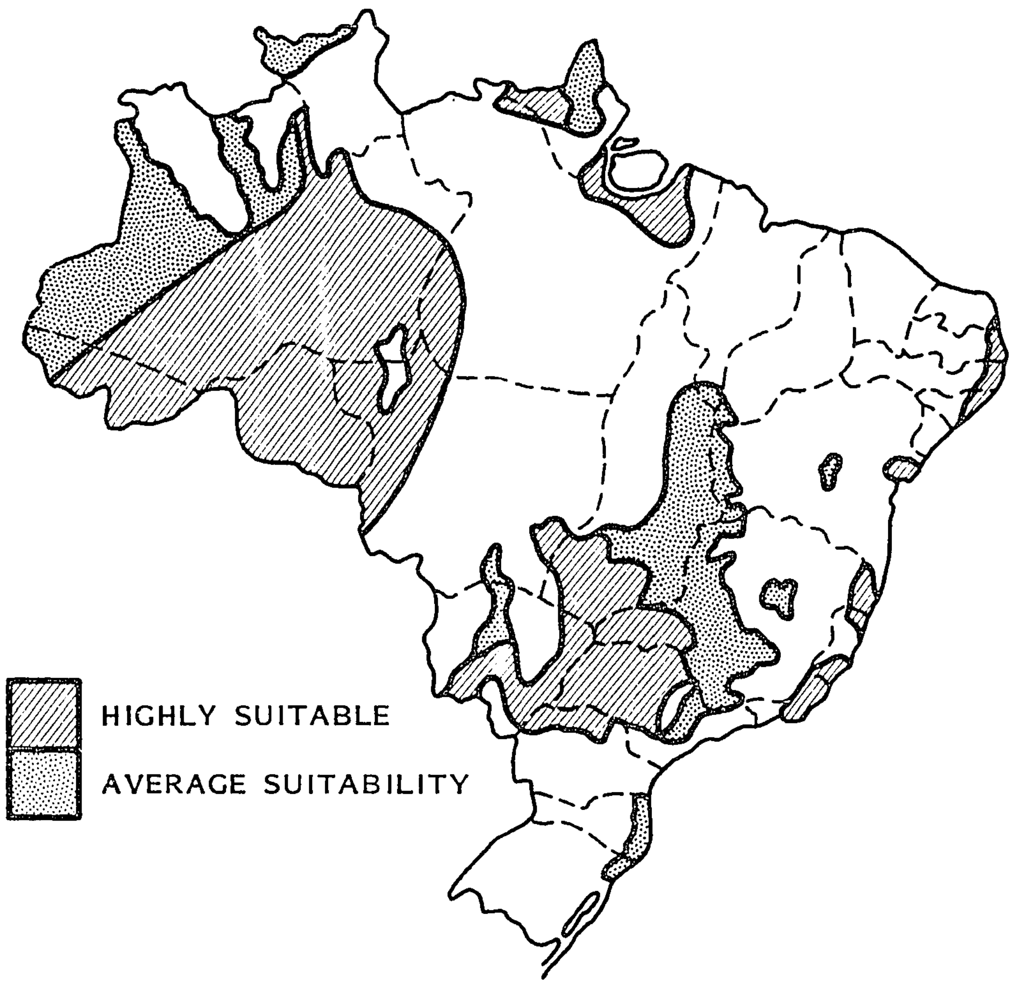

Figure 16. Areas of Brazil which are suitable for the cultivation of sugar cane

are considered to be highly suitable and moderately suitable for the production of sugar cane. The expansion of the area cultivated with sugar cane is guaranteed by the suitability of this crop to a large portion of Brazil's territory.[1]

The Proálcool consists of a series of incentives given towards the production and the domestic consumption of ethanol as a fuel and as an input to the chemical industry. The policy instruments utilized for the achievement of government-established targets have included: the prices paid to producers of ethanol and to producers of sugar; prices charged to consumers of ethanol, gasoline, and sugar; subsidized interest rates on loans offered towards the production of ethanol; and price subsidies for the ethanol utilized in the chemical industry.

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[1]In 1979, the cultivation of sugar cane occupied an area of approximately 2.4 million hectares, which is equivalent to four percent of Brazil's total arable and permanent crop land base.

Measures of Net Income

The levels of the policy variables defined by the government since the creation of the Proálcool have provided the adequate set of incentives to stimulate the production of ethanol in Brazil. During the 1982-1983 crop year, the production of ethanol (hydrous and anhydrous) reached 5.3 billion litres, which corresponded to 14 percent of all the trnasportation fuels, and 6 percent of all the petroleum used in Brazil.[1]

From 1976 until 1980, approximately 61 billion cruzeiros of 1980 have been transferred to producers of ethanol in the form of subsidized credit, During this same period, the total gross income (price received minus cost--including taxes collected by the government) of producers of hydrous and anhydrous ethanol is estimated

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[1]Sociedade de Produtores de Açúcar e Álcool, Avaliação Econômica e Social do Proálcool, pp. 19 and 29.

at 29.2 billion cruzeiros of 1980 (27.2 billion cruzeiros by producers of anhydrous ethanol, and 2.0 billion cruzeiros by producers of hydrous ethanol).[1]

The results of this study also indicate that the producers of sugar have been able to increase the value of their annual gross income by more than 200 percent between 1975 and 1980 (from 20.6 billion to 63.7 billion cruzeiros of 1980),[2] while the production of sugar increased by 30 percent over this same period. This result is a consequence of the combined effect of an increase in the quantity exported of sugar of 50 percent (from 1.7 million metric tons in 1975 to 2.6 million metric tons in 1980), and a reduction of 27 percent in the cost of producing sugar (from approximately 795 cru-

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[1]See Table 21 in Chapter XII. In 1980, the annual gross income accrued by producers of anhydrous and hydrous ethanol was 14.3 billion and 1.9 billion cruzeiros, respectively.

[2]See Table 22 in Chapter XII.

zeiros of 1980 per ton in 1975 to approximately 580 cruzeiros of 1980 per ton in 1980).

Furthermore, the policy of pricing the gasohol (the ethanol-gasoline mixture sold in Brazil) at levels above its cost have netted the government the sizable amount of 1,314 billion cruzeiros of 1980 between the years of 1976 and 1980.[1] This value dwarfs the total amount of transfers from the government to producers of ethanol and sugar between 1976 and 1980, which is estimated at 120 billion cruzeiros of 1980.

Finally, it is estimated that in 1980, when the price of petroleum reached its new plateau at 28.67 dollars of 1980 per barrel, the cost of gasoline was only slightly lower than the cost of ethanol, if the financial costs of imported oil are <u>not</u> taken into account (the value of savings for using ethanol in substitution to gasoline was $SAVPROA_{1980} = -3$ billion

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[1]See Table 23 in Chapter XII.

cruzeiros of 1980).[1] If the financial costs of imported oil[2] are considered--at 9 percent per year during 10 years--the value of savings for using ethanol instead of gasoline (SAVPROAl) is estimated at 22 billion cruzeiros in 1980.[3]

However, a full measure of the impact of the Proálcool upon the economy is much greater than the simple net savings figure presented above. One should also take into account the multiplicative effect of the income generated by the production of ethanol, which is retained in the country. World Bank estimates show that the production of one million litres of ethanol from sugar cane employs 32 direct workers in the average: 7

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[1] Refer to Table 23 in Chapter XII.

[2] Since 1973 Brazil has acquired a substantial amount of foreign debt, largely to pay for its oil importation bills.

[3] This figure is equivalent to 417 million dollars of 1980, using the free exchange rate in 1980. From 1976 until May of 1982, the total value of investments under the Proálcool have been estimated at 6 billion dollars. See Sociedade de Produtores de Açúcar e Álcool, <u>Avaliação Econômica e Social do Proálcool</u>, p. 8.

in industrial activities, and 25 in agricultural activities. The production of 5.3 billion litres of ethanol in the 1982-1983 crop year imply that 170,000 new direct jobs were created with the Proálcool. The amount of indirect jobs related to the production of ethanol can be even bigger.

All these observations indicate the appropriateness of the National Alcohol Program as a response to Brazil's energy challenges.

Proálcool's Objectives for 1985

The model developed in this study is also suitable for policy analyses. It is estimated that in order to achieve the government's production objective of 10.7 billion litres of ethanol in 1985, the gasohol mixture consumed by 10 million vehicles in 1985 must have a proportion of 16.5 percent of anhydrous ethanol.

A number of policy alternatives are estimated, as combinations of possible levels of interest rate subsidy and prices paid to producers of ethanol (see Chapter XI), necessary for the achievement of the government's production targets of hydrous and anhydrous ethanol.

It is estimated that the price paid to producers of sugar cane must be significantly larger during the period of 1981 to 1984 than it was in the past (933.5 cruzeiros of 1980 per ton of sugar cane in 1981-1984, in comparison with 585 cruzeiros per ton of cane in 1980) for the target production of sugar cane to be reached in 1985.

It is also estimated that the domestic price of sugar in 1985, which is consistent with the government's plans, is the same price level observed in 1980.

Conclusion

Historically, the cultivation of sugar cane has been important to Brazil's economic development. In future years, this role is going to be enhanced by the contribution it is giving to the partial solution of Brazil's energy problem.

APPENDIX A.

ADDITIONAL RELATED TOPICS

The World's Reserves of Petroleum

In 1975, the world's known reserves of petroleum amounted to 580 billion barrels. The discovery of additonal oil deposits in Mexico and the Soviet Union raised the volume of known reserves to 620 billion barrels in 1982.

During recent years, the world has consumed approximately 5.5 percent of its known reserves per year, which indicates that unless new oil fields are unveiled the _black gold_ will become gradually a more expensive product, due to its relative scarcity.

The Use of Ethanol in the Chemicals Industry

A key factor for the achievement of Proálcool's targets is the successful substitution of petroleum-derived products by ethanol.

According to a report released by the Secretariat of Industrial Technology of the Ministry of Industry and Commerce:

> As petrochemicals usually have a greater added-value than petroleum-based fuels, it is expected that, as crude oil becomes more expensive and scarce, there will be a world-wide trend to use ever larger portions of it for producing petrochemicals.[1]

The consumption of petrochemicals in Brazil has increased at a fast pace, averaging 15 percent annual growth during the 1970s. Growth in the petrochemicals industry is expected to continue in the future, which indicates the appropriateness of the incentives given by the government to the use of ethanol as a raw material in this industry, if oil independence is to be achieved.

Ethanol can be used in the chemicals industry for

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[1]Brazil, Ministry of Industry and Commerce, Secretariat of Industrial Technology, <u>Assessment of Brazil's National Alcohol Program</u>, p. 14.

the production of ethylene, butadiene, acetic acids, octanol, ethyl esters, and other products. The use of ethanol for the production of ethylene, the most important of these basic products, has been made possible by a government incentive defined under the decree nº 83,700, of July 5, 1979. This decree determined that the price of one thousand litres of ethanol used as raw-material to the chemicals industry would not exceed 35 percent of the price of one metric ton of ethylene.[1]

In 1981, the chemicals industry used 300 million litres of ethanol. The target consumption level for the chemicals industry under the Proálcool is 1,500 million litres in 1985.

Enrironmental Impacts

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[1]To produce one metric ton of ethylene approximately 2.2 thousand litres of ethanol are needed as input, or 5.24 metric tons of nafta.

The Combustion of Ethanol

The addition of anhydrous ethanol to gasoline produces a high octane fuel, which dispenses the use of lead-based anti-knock additives.

Studies carried out by the CETESB (Companhia Técnica de Saneamento Ambiental do Estado de São Paulo) have revealed that straight ethanol engines expel 65 percent less carbon monoxide than the conventional gasoline engines.(see Table 24). Carbon monoxide is commonly known as a poison to humans, as it affects the system that transports oxigen in our body.

Ethanol engines also produce less than one third of the hydrocarbonates produced by gasoline engines. These substances have been associated with headaches and drowsiness.

The trade-off lies in the larger output of aldehydes of ethanol engines--four times larger--in comparison with gasoline engines. Aldehydes have been associated with cancer, eye irritations, and respiratory

TABLE 24

COMPARISON OF THE EMISSIONS FROM VEHICLES THAT UTILIZE HYDROUS ETHANOL AND GASOLINE AS FUELS

(in Ounces per One Hundred Miles)

Substance	Hydrous Ethanol	Gasoline	Effects
Carbon Monoxide	81.63	236.67	Damages the body ability of transporting oxygen
Hidrocarbonates	6.98	22.20	Headaches and drowsiness
Nitrogen Oxide	7.32	6.47	Irritation of the respiratory system
Aldehydes	0.89	0.16	Cancer, eye irritation, and irritation of the respiratory system

SOURCE: "Uma nova poluição," Isto é, p. 36.

problems.

Studies are being carried out to verify whether the amounts of aldehydes produced by the emissions from vehicles that utilize hydrous ethanol as fuel are significantly large to affect human health,[1] but no conclusive results have been reached yet.

Scums (Vinhoto)

From the ethanol distilling process a large volume of scums is produced. This is the residue left in the distillation pans after the evaporation of the ethanol. Scums are very rich in minerals, most notably potash, and can be used with great success as fertilizer for sugar cane, and other crops.

However, the volume of scums obtained in an ethanol distilling plant is, in many circumstances, larger

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[1] "Uma nova poluição," Isto é, 1 June 1983, p.36.

than the amount that can be added to the soil economically, due to the transportation costs involved. When that occurs, part of the scums is disposed of in ways that can affect negatively the ecosystem.

However, fertilizers are in general very expensive in Brazil, and incentives should be given for the economical utilization of scums.

APPENDIX B.

THE DATA AND THEIR SOURCES

Indexes

The data in the form of indexes utilized in this study are presented in Table 25.

WPI

This is the wholesale price index, products for domestic use, all commodities (base 1965-1967=100) found in Fundação Getúlio Vargas, Instituto Brasileiro de Economia, Conjuntura Econômica (Rio de Janeiro: IBRE, various issues).

X

This variable is WPI normalized for 1980, and is defined as:

$$X = WPI/5,409$$

TABLE 25

DATA USED IN THIS STUDY--INDEXES

Year	WPI	X	IPPCANE	USCPI
1958	3.829	0.0007078	. . .	100.7
1959	5.27	0.0009743	. . .	101.5
1960	6.92	0.0012793	. . .	103.1
1961	9.72	0.0017970	. . .	104.2
1962	14.6	0.0026992	. . .	105.4
1963	25.7	0.0047513	. . .	106.7
1964	46.6	0.00862	. . .	108.1
1965	71.6	0.01324	. . .	109.9
1966	101	0.01867	100	113.1
1967	128	0.02366	113	116.3
1968	157	0.02903	151	121.2
1969	187	0.03457	191	127.7
1970	223	0.04123	236	135.3
1971	271	0.05010	264.42	141.0
1972	319	0.05898	300.60	145.7
1973	368	0.06803	358.25	154.8
1974	475	0.08782	506.83	171.7
1975	607	0.11222	792.33	187.5
1976	852	0.15752	1,155.0	198.3
1977	1,198	0.22148	1,566.2	211.1
1978	1,664	0.30764	2,131.3	227.2
1979	2,585	0.47791	3,242.4	252.8
1980	5,409	1.00000	6,833.8	287.0
1981	10,710	1.98003	. . .	312.9
1982	20,948	3.87280	. . .	. . .

Year	IPPFARM	IMAQEQT	ICOMBLUB
1958	. . .	. . .	3.38608
1959	. . .	. . .	5.26123
1960	. . .	. . .	5.82333
1961	. . .	. . .	9.74818
1962	. . .	. . .	12.70903
1963	. . .	. . .	22.53590
1964	. . .	. . .	44.59965
1965	. . .	. . .	80.45446
1966	100	. . .	100
1967	115	. . .	120
1968	138	. . .	155
1969	164	103	195
1970	193	116	225
1971	231	130	276
1972	283	149	350
1973	353	168	401
1974	618	206	641
1975	860	269	881
1976	1,055	354	1,398
1977	1,561	492	2,112.1
1978	2,161	653	2,800.6
1979	3,386	943	4,699.4
1980	7,353	1,748	12,188.94
1981	. . .	. . .	. . .
1982	. . .	. . .	. . .

IPPCANE

This is the index of prices received by farmers for sugar cane (base 1966=100) found in Fundação Getúlio Vargas, Instituto Brasileiro de Economia, Conjuntura Econômica.

USCPI

This is the consumer price index found in U.S., Department of Commerce, Bureau of Economic Analysis, Survey of Current Business (Washington, D.C.: Government Printing Office, various issues).

IPPFARM

This is the index of prices paid by farmers in São Paulo found in Fundação Getúlio Vargas, Instituto Brasileiro de Economia, Conjuntura Econômica.

IMAQEQT

This is the wholesale price index, products for domestic use, machinery and equipment (base 1969=100) found in Fundação Getúlio Vargas, Instituto Brasileiro de

Economia, Conjuntura Econômica.

ICOMBLUB

This is the wholesale price index, industrial products, chemical industry, fuels and lubricants (base 1966=100) found in Fundação Getúlio Vargas, Instituto Brasileiro de Economia, Conjuntura Econômica.

Sugar Cane

All the data related with sugar cane is presented in Table 26.

PRODCANE and CRSCANE

These are the total quantity of sugar cane produced and the quantity of sugar cane crushed in Brazil in metric tons per year. They are found in Brazil, Secretaria de Planejamento da Presidência da República, Fundação Instituto Brasileiro de Geografia e Estatística, Anuário Estatístico do Brasil.

TABLE 26

DATA USED IN THIS STUDY--SUGAR CANE

Year	PRODCANE	CRSCANE	PPACANE	COSTCANE
1958	50,020,121	33,507,353	. . .	. . .
1959	53,512,330	35,111,362	. . .	. . .
1960	56,926,882	37,029,410	. . .	. . .
1961	59,377,397	36,578,574	. . .	. . .
1962	62,534,516	35,180,813	. . .	. . .
1963	63,722,895	34,249,196	. . .	. . .
1964	66,398,978	38,767,130	. . .	. . .
1965	75,852,866	51,200,265	. . .	. . .
1966	75,787,512	42,752,389	458.426	. . .
1967	77,086,529	49,963,699	409.056	. . .
1968	76,610,500	43,601,565	445.467	. . .
1969	75,247,090	46,985,893	473.215	. . .
1970	79,753,000	57,077,411	490.206	. . .
1971	79,595,000	58,925,619	451.881	$522.517
1972	95,074,000	67,870,058	436.450	543.867
1973	91,994,024	75,807,428	450.946	587.994
1974	95,623,685	74,454,749	494.212	806.488
1975	91,524,559	68,322,619	604.614	767.980
1976	103,173,449	87,583,795	627.876	809.198
1977	120,081,700	105,783,000	605.555	712.001
1978	129,144,950	109,714,000	593.267	644.406
1979	138,898,882	117,720,000	580.971	724.314
1980	148,650,563	128,155,517	585.190	671.866
1981	153,858,357	. . .	. . .	. . .

PPACANE

The price of sugar cane paid to producers is computed using the index IPPCANE for the years of 1966 to 1979. The price paid to producers of cane in 1980 is used as the base, and comes from Cooperativa Central dos Produtores de Açúcar e Álcool do Estado de São Paulo, Aspectos Econômicos da Produção de Cana, Açúcar e Álcool, Período 1978/1980. The variable is deflated using the index X.

COSTCANE

Data for the years of 1973 to 1980 come from Cooperativa Central dos Produtores de Açúcar e Álcool do Estado de São Paulo, Aspectos Econômicos da Produção de Cana, Açúcar e Álcool, Período 1978/1980, pp. 17 and 82. The original data in this reference is for the cost of sugar cane in the month of September. These values were transformed into yearly averages using the monthly index WPI. Data for the years 1971 and 1972 were estimated using the index of prices paid by farmers, all commodities. The variable is deflated using the index X.

Sugar

All the data related with sugar are presented in Table 27.

PRODSUG and DCSPCAP

These variables were obtained in Brazil, Secretaria de Planejamento da Presidência da República, Fundação Instituto Brasileiro de Geografia e Estatística, Anuário Estatístico do Brasil.

XQSUG

This variable is found in United Nations, Food and Agriculture Organization, Trade Yearbook (Rome: FAO, various issues).

COSTSUG

Data for the years of 1973 to 1978 are found in Cooperativa Central dos Produtores de Açúcar e Álcool do

TABLE 27

DATA USED IN THIS STUDY--SUGAR

Year	PRODSUG	DCSPCAP	XQSUG
1958	3,003,613	0.0341090	758,182
1959	3,108,253	0.0314500	616,081
1960	3,318,719	0.0321300	769,041
1961	3,354,137	0.0328100	783,292
1962	3,238,061	0.03348	445,225
1963	3,067,838	0.03416	523,386
1964	3,425,286	0.03484	252,074
1965	4,660,396	0.03552	759,979
1966	3,881,092	0.03619	1,004,551
1967	4,318,240	0.03687	1,001,315
1968	4,204,238	0.03755	1,026,263
1969	4,216,010	0.03823	1,099,062
1970	5,069,919	0.03735	1,126,462
1971	5,081,434	0.03725	1,261,223
1972	5,925,731	0.03867	2,534,910
1973	6,679,727	0.04034	2,797,926
1974	6,672,720	0.04147	2,356,731
1975	6,017,061	0.04397	1,730,774
1976	6,851,271	0.04359	1,167,334
1977	8,305,749	0.04199	2,454,586
1978	7,475,676	0.04252	1,961,516
1979	6,979,589	0.04500	1,829,228
1980	7,843,518	0.04568	2,572,336

Year	COSTSUG	DPSUG	XPSUG
1958	. . .	. . .	0.215571
1959	. . .	. . .	0.196184
1960	. . .	. . .	0.208969
1961	. . .	15.3032	0.230689
1962	. . .	16.5975	0.241548
1963	. . .	19.2577	0.371651
1964	. . .	22.2280	0.347043
1965	. . .	20.7748	0.194924
1966	. . .	16.8697	0.203438
1967	. . .	17.7483	0.198214
1968	. . .	17.5706	0.234384
1969	774.123	18.3675	0.235301
1970	731.088	18.5555	0.238844
1971	674.209	18.3627	0.246846
1972	656.473	18.2278	0.313585
1973	641.628	18.3730	0.366246
1974	708.283	18.2198	0.937585
1975	794.838	15.7725	0.972620
1976	726.177	18.2205	0.380057
1977	695.309	19.8887	0.256283
1978	703.940	19.7637	0.225439
1979	654.376	18.4450	0.225792
1980	579.696	17.4150	0.500811

Estado de São Paulo, Aspectos Econômicos da Produção de Cana, Açúcar e Álcool, Período 1978/1980, p. 20. The original data, which refer to the cost in the month of September, were transformed into annual data by the monthly index WPI. Data for the years of 1969 to 1972, 1979 and 1980 were estimated using the index IMAQEQT. The variable is deflated using the index X.

DPSUG

This is the mean of the retail prices of refined and crystal sugar in São Paulo. These prices are found in Brazil, Secretaria de Planejamento da Presidência da República, Fundação Instituto Brasileiro de Geografia e Estatística, Anuário Estatístico do Brasil. The variable is deflated using the index X.

XPSUG

This variable is obtained by dividing the value of sugar exports from Brazil by the quantity exported. The source is United Nations, Food and Agriculture

Organization, Trade Yearbook.

Hydrous and Anhydrous Ethanol

All the data for hydrous ethanol are presented in Table 28. The data for anhydrous ethanol are presented in Table 29.

PROET185, PROET200, GP200

These variables are found in Brazil, Secretaria de Planejamento da Presidência da República, Fundação Instituto Brasileiro de Geografia e Estatística, Anuário Estatístico do Brasil, and Brazil, Ministério da Indústria e do Comércio, Ministério dos Transportes, Estudo do Transporte do Álcool e Acompanhamento do Programa Nacional do Álcool--Proálcool, Relatório de Atividades de 1981, p. 30.

CETH185

This variable is found in Brazil, Ministério da

TABLE 28

DATA USED IN THIS STUDY--HYDROUS ETHANOL

Year	PROET185	CETH185	CQUIM
1958	154,752	. . .	. . .
1959	135,325	. . .	. . .
1960	287,698	. . .	. . .
1961	240,329	. . .	. . .
1962	250,212	. . .	. . .
1963	276,268	. . .	. . .
1964	313,378	. . .	. . .
1965	253,186	. . .	. . .
1966	312,826	. . .	. . .
1967	333,125	. . .	. . .
1968	328,100	. . .	. . .
1969	361,246	0	300,000
1970	392,311	0	300,000
1971	230,267	0	300,000
1972	283,141	0	300,000
1973	333,107	0	341,507
1974	399,808	0	419,587
1975	359,790	0	316,248
1976	369,803	0	411,337
1977	297,724	0	370,571
1978	392,629	0	365,000
1979	618,246	17,500	420,000
1980	1,503,613	429,179	486,015
1981	2,750,000	1,391,709	401,000

Year	PRET185	COSTE185	MARG18	PPET185
1958	. . .	. . .	. . .	. . .
1959	. . .	. . .	. . .	. . .
1960	. . .	. . .	. . .	. . .
1961	. . .	. . .	. . .	. . .
1962	. . .	. . .	. . .	. . .
1963	. . .	. . .	. . .	. . .
1964	. . .	. . .	. . .	. . .
1965	. . .	. . .	. . .	. . .
1966	. . .	. . .	. . .	. . .
1967	. . .	. . .	. . .	. . .
1968	. . .	. . .	. . .	. . .
1969	9.1611	22.5596	-13.3980	0
1970	8.5700	21.3052	-12.7350	0
1971	8.9470	19.6476	-10.7010	0
1972	9.6385	19.1307	-9.4920	0
1973	9.5726	18.6981	-9.1254	0
1974	11.8549	17.7626	-5.9076	0
1975	12.7504	18.1509	-5.4005	0
1976	14.4147	17.0175	-2.6029	0
1977	15.4879	16.8206	-1.3327	0
1978	14.7855	16.0729	-1.2874	0
1979	19.4077	14.9412	4.4665	14.1450
1980	17.7669	13.2360	4.5309	17.5300
1981	. . .	. . .	. . .	21.2421

TABLE 29

DATA USED IN THIS STUDY--ANHYDROUS ETHANOL

Year	PROET200	GP200	XQETH
1958	280,544	277,323	3,049
1959	343,397	304,650	3,804
1960	188,570	232,769	71,359
1961	181,500	130,687	41,860
1962	132,374	139,843	14,621
1963	111,246	62,809	26,618
1964	62,193	82,752	45,480
1965	305,872	224,798	6,522
1966	362,044	338,301	53,602
1967	432,592	369,495	55,321
1968	171,091	191,300	15,420
1969	98,423	31,800	7,597
1970	233,038	183,606	6,825
1971	394,479	253,836	4,405
1972	400,832	391,142	4,403
1973	319,705	308,812	43,579
1974	215,129	190,170	90,187
1975	220,340	162,165	63,538
1976	272,352	171,572	31,735
1977	1,087,924	638,977	11
1978	1,943,455	1,504,119	12,207
1979	2,832,036	2,219,084	92,591
1980	2,172,556	2,253,108	308,850

Year	PRET200	COSTE200	MARG20
1958	. . .	. . .	. . .
1959	. . .	. . .	. . .
1960	. . .	. . .	. . .
1961	. . .	. . .	. . .
1962	. . .	. . .	. . .
1963	. . .	. . .	. . .
1964	. . .	. . .	. . .
1965	. . .	. . .	. . .
1966	. . .	. . .	. . .
1967	. . .	. . .	. . .
1968	. . .	. . .	. . .
1969	10.4105	23.6226	-13.2120
1970	9.7387	22.3091	-12.5700
1971	10.1669	20.5734	-10.4060
1972	10.9530	20.0321	-9.0790
1973	10.8780	19.5791	-8.7011
1974	13.4716	18.5996	-5.1280
1975	14.4891	19.0062	-4.5171
1976	16.3803	17.8194	-1.4392
1977	17.5999	17.6132	-0.0133
1978	16.8016	16.8302	-0.0286
1979	21.5926	15.6452	5.9474
1980	20.2144	13.8597	6.3547

Indústria e do Comércio, Comissão Executiva Nacional do Álcool, Programa Nacional do Álcool--Proálcool, Relatório Anual 1981 (Brasília: CENAL, 1981), and Brazil, Ministério da Indústria e do Comércio, Ministério dos Transportes, Estudo do Transporte do Álcool e Acompanhamento do Programa Nacional do Álcool--Proálcool, Relatório de Atividades de 1981.

PRET185 and PRET200

Data for the years of 1978 to 1980 were obtained in Cooperativa Central dos Produtores de Açúcar e Álcool do Estado de São Paulo, Aspectos Econômicos da Produção de Cana, Açúcar e Álcool, Período 1978/1980, p. 98, and Brazil, Ministério da Indústria e do Comércio, Comissão Executiva Nacional do Álcool, Programa Nacional do Álcool--Proálcool, Relatório Anual 1980 (Brasília: CENAL, 1980). Data for the month of September were annualized by the monthly index WPI. Data for the years of 1969 to 1977 were estimated using the index ICOMBLUB. Values are deflated by the index X.

COSTE185 and COSTE200

Datum for 1980 is found in Borges, Desenvolvimento Econômico. Other years were estimated using the index IMAQEQT. All values were deflated using the index X.

PPET185

Data was obtained from Carlino Nastari, personal letter. Original sources are the reports released by the CNP. Prices were adjusted to yearly averages. Values were deflated using the index X.

CQUIM

Data for the years of 1973 to 1977 were obtained from Brazil, Ministério da Indústria e do Comércio, Instituto do Açúcar e do Álcool, Relatório Anual 1978 (Brasília: IAA-MIC, 1978), p. 11. Data for the years of 1978 and 1979 were obtained from Borges, Viabilidade Econômica da Produção de Cana e Álcool no Brasil: Uma Abordagem Dinâmica. Datum for 1980 was obtained from Brazil, Ministério da Indústria e do Comércio, Comissão Executiva Nacional do Álcool, <u>Programa Nacional do Álcool--Proálcool, Relatório Anual 1980</u>. Datum for 1981 was obtained from Brazil, Ministério da Indústria e do Comércio, Comissão Executiva Nacional do Álcool, <u>Programa Nacional do Álcool--Proálcool, Relatório Anual 1981</u>, p. 14. Data for the years of 1969 to 1972 are the author's estimates.

<u>XQETH</u>

Data were obtained from Brazil, Secretaria de Planejamento da Presidência da República, Fundação Instituto Brasileiro de Geografia e Estatística, <u>Anuário Estatístico do Brasil</u>.

Gasohol

The data related with the consumption, price and cost of gasohol in Brazil is presented in Table 30.

<u>CGASA</u>

Data were obtained from Brazil, Secretaria de

TABLE 30

DATA USED IN THIS STUDY--GASOHOL

Year	CGASA	CGASAVEH	PPGAS	PBPETR	COSTGAS
1958	3,812,398	. . .	13.2661	5.9281	3.2094
1959	3,840,853	. . .	14.9748	5.4290	2.6638
1960	4,285,930	. . .	12.6158	5.2055	2.3157
1961	4,484,760	. . .	15.0361	4.9578	2.3638
1962	5,064,447	. . .	13.0520	4.9013	2.2184
1963	5,493,492	. . .	13.1479	4.8416	1.8089
1964	5,997,375	. . .	14.3513	4.7789	2.5794
1965	5,982,496	. . .	16.8487	4.7006	2.1602
1966	6,573,741	. . .	14.9952	4.5676	1.7497
1967	7,144,976	. . .	13.9451	4.4420	1.5914
1968	8,052,300	. . .	14.8145	4.2624	1.6138
1969	8,492,400	3.45000	15.6196	4.0454	1.7138
1970	9,340,480	3.40000	15.0385	3.8182	1.6042
1971	10,074,489	3.35816	15.3687	4.4577	1.8956
1972	11,217,444	3.30490	16.4474	4.6881	1.9665
1973	12,933,403	3.31677	16.3152	6.0811	2.4155
1974	13,840,674	3.08419	20.2695	16.3140	6.2182
1975	14,354,518	2.82075	21.7429	16.4087	6.3475
1976	14,546,411	2.58769	24.5690	16.6584	6.3765
1977	13,976,082	2.30071	26.4580	16.8584	6.4744
1978	15,100,030	2.31325	24.6070	16.0427	6.0992
1979	15,537,571	2.20679	22.1591	19.2658	7.8228
1980	15,937,264	2.15568	33.7900	28.6700	12.3566
1981	. . .	. . .	35.9792	29.8098	. . .

Planejamento da Presidência da República, Fundação Instituto Brasileiro de Geografia e Estatística, Anuário Estatístico do Brasil, and Brazil, Ministério da Indústria e do Comércio, Ministério dos Transportes, Estudo do Transporte do Álcool e Acompanhamento do Programa Nacional do Álcool--Proálcool, Relatório de Atividades de 1981, p. 30.

CGASAVEH

This variable is the quotient of CGASA and VEHGASC.

PPGAS

Data for the years of 1978 and 1981 were obtained from Carlino Nastari, personal letter. Original sources are the reports released by the CNP. Data for the years of 1958 to 1977 were estimated using the index ICOMBLUB. All values were deflated using the index X.

PBPETR

This variable is found in International Monetary Fund, International Financial Statistics, various issues. Values were deflated using the index USCPI.

<u>COSTGAS</u>

Borges[1] has observed that the cost of gasoline is approximately 1.3 times the cost of petroleum in Brazil. Therefore, this variable is constructed in the following manner:

COSTGAS = ((1.3)(PBPETRN)(EXCHRATE))/((X)(159)

It should be noted that one barrel is equivalent to 159 litres, and that PBPETRN is the price of oil in Saudi Arabia in nominal dollars.

R1, R2, R3, R4, and R5

The data depicting these coefficients are presented in Table 31.

<u>R1</u>

This variable is defined as:

---

[1]Borges, <u>Desenvolvimento Econômico</u>, p. 39

TABLE 31

DATA USED IN THIS STUDY--R1, R2, R3, R4, R5

Year	R1	R2	R3	R4	R5
1958	0.072743	12.3678	12.8316	9.3200	. . .
1959	0.079318	12.3898	12.8544	9.3366	. . .
1960	0.054310	12.4083	12.8737	9.3506	. . .
1961	0.029140	12.3734	12.8374	9.3243	. . .
1962	0.027613	12.4416	12.9082	9.3756	. . .
1963	0.011433	12.6684	13.1435	9.5465	. . .
1964	0.013798	13.1010	13.5923	9.8726	. . .
1965	0.037576	12.5415	13.0118	9.4509	. . .
1966	0.051462	11.8326	12.2763	8.9167	. . .
1967	0.051714	12.3794	12.8436	9.3288	. . .
1968	0.023757	11.8682	12.3133	8.9436	. . .
1969	0.003745	12.9068	13.3908	9.7262	0
1970	0.019657	12.8130	13.2935	9.6555	0
1971	0.025196	13.1861	13.6806	9.9367	0
1972	0.034869	13.1417	13.6345	9.9032	0
1973	0.023877	13.3032	13.8021	10.0249	0
1974	0.013740	13.1747	13.6687	9.9280	0
1975	0.011297	13.3373	13.8375	10.0506	0
1976	0.011795	15.0610	15.6258	11.3495	0
1977	0.045719	13.7641	14.2803	10.3722	0
1978	0.099610	13.6420	14.1535	10.2802	0
1979	0.142821	13.3528	13.8536	10.0623	3.62845
1980	0.141374	13.2	13.75	10	2.79712
1981	. . .	. . .	. . .	. . .	3.76486

R1 = GP200/CGASA

<u>R2, R3, and R4</u>

Read Chapter IX for a detailed explanation of how these variables were derived.

<u>R5</u>

This variable is defined as:

R5 = CETH185/VECETH

Interest Rates

The data related to interest rates are presented in Table 32.

<u>INTRATE</u>

Interest rates vary widely according to the liquidity of the borrower, length of credit, guarantees offered, and other factors. This variable is estimated as:

TABLE 32

DATA USED IN THIS STUDY--INTEREST RATES

Year	INTRATE	SUBINTRT	INTDIFF	DISCRATE
1958	16.741	. . .	. . .	8.00
1959	50.825	. . .	. . .	8.00
1960	42.268	. . .	. . .	8.00
1961	54.624	. . .	. . .	8.00
1962	67.778	. . .	. . .	8.00
1963	102.637	. . .	. . .	8.00
1964	109.786	. . .	. . .	8.00
1965	72.425	. . .	. . .	12.00
1966	55.433	12.00	0.434330	12.00
1967	36.089	12.00	0.240891	22.00
1968	30.586	12.00	0.185859	22.00
1969	25.796	12.00	0.137962	20.00
1970	25.989	12.00	0.139893	20.00
1971	29.058	12.00	0.170583	20.00
1972	23.911	12.00	0.119114	20.00
1973	20.737	12.00	0.087367	18.00
1974	39.253	12.00	0.272527	18.00
1975	37.516	15.00	0.225158	18.00
1976	54.489	15.00	0.394893	28.00
1977	54.824	15.00	0.398239	30.00
1978	52.513	15.00	0.375125	33.00
1979	74.721	26.14	0.484806	35.00
1980	147.482	47.70	0.997816	38.00

$$INTRATE = (((WPI_t - WPI_{t-1})/WPI_{t-1}))(100)(1.35)$$

SUBINTRT

Data were obtained from Brazil, Ministério da Indústria e do Comércio, Ministério dos Transportes, Estudo do Transporte do Álcool e Acompanhamento do Programa Nacional do Álcool--Proálcool, Relatório de Atividades de 1981, and Brazil, Ministry of Industry and Commerce, Secretariat of Industrial Technology, Assessment of Brazil's National Alcohol Program.

INTDIFF

This variable is defined as:

$$INTDIFF = (INTRATE - SUBINTRT)/100$$

DISCRATE

The is the discount rate offered by the Central Bank to other banks in Brazil, from International Monetary Fund, International Financial Statistics. This variable is presented for comparison with the estimated values of INTRATE.

Vehicles

The data related to the number of vehicles in operation in Brazil are presented in Table 33. All the variables were derived from the original data on the number of vehicles purchased in each year, found in Brazil, Ministério da Indústria e do Comércio, Comissão Executiva Nacional do Álcool, Programa Nacional do Álcool--Proálcool, Relatório Anual 1981, and in Anfavea, Planejamento Econômico e Estatístico, data collected during visit. The percentage of cars junked each year according to their age was obtained from the first source above.

Credits

All the data referring to credits given to

TABLE 33

DATA USED IN THIS STUDY--VEHICLES

Year	VEHETH	VECETH	VEHGAS	VEHGASC
1968	0	. . .	2,307,094	. . .
1969	0	0	2,549,456	2,460,000
1970	0	0	2,875,841	2,750,000
1971	0	0	3,203,664	3,000,000
1972	0	0	3,687,227	3,394,189
1973	0	0	4,251,558	3,899,393
1974	0	0	4,913,678	4,487,618
1975	0	0	5,524,977	5,093,897
1976	0	0	6,151,585	5,701,399
1977	0	115	6,652,958	6,249,677
1978	0	565	7,267,522	6,787,622
1979	9,645	4,823	7,897,551	7,395,813
1980	297,226	153,436	8,240,820	7,853,153
1981	442,089	369,658	8,283,942	8,036,016
1982	625,007	552,769	8,290,711	8,064,485

producers at subsidized interest rates are presented in Table 34.

CREDCANE and CREDCOO

Data for these two variables were obtained from Brazil, Secretaria de Planejamento da Presidência da República, Fundação Instituto Brasileiro de Geografia e Estatística, Anuário Estatístico do Brasil. All the values of these variables were deflated using the index X.

CREDETH

Data for this variable were found in Brazil, Ministério da Indústria e do Comércio, Comissão Executiva Nacional do Álcool, Programa Nacional do Álcool--Proálcool Relatório Anual 1981. All the figures were deflated using the index X.

Some Exogenous Variables

Data related to a few remaining exogenous

TABLE 34

DATA USED IN THIS STUDY--CREDITS

Year	CREDCANE	CREDETH	CREDCOO
1958	3,118,106	. . .	. . .
1959	3,091,768	. . .	. . .
1960	2,418,417	. . .	. . .
1961	. . .	. . .	. . .
1962	616,478	. . .	. . .
1963	753,893	. . .	. . .
1964	2,048,107	. . .	. . .
1965	1,799,475	. . .	. . .
1966	2,277,832	. . .	. . .
1967	2,601,983	. . .	. . .
1968	2,757,625	. . .	. . .
1969	3,869,518	0	231,401
1970	4,307,674	0	218,300
1971	3,872,445	0	199,594
1972	5,123,595	0	187,331
1973	7,780,538	0	166,856
1974	10,608,871	0	122,198
1975	16,348,003	0	730,803
1976	18,648,639	2,412.5	830,802
1977	17,321,826	9,183.6	915,123
1978	19,701,639	13,155.2	793,085
1979	20,509,760	9,047.8	1,000,680
1980	25,727,426	17,788.0	750,000

variables are presented in Table 35.

<u>POP and LABCOST</u>

The population data derived from census reports with measures of the size of the population every ten years. Intermediary measures were estimated using a constant rate of growth in each decade. The data on the cost of labor was transformed into averages for the year, and deflated by the index X.

The source of data for these two variables is Brazil, Secretaria de Planejamento da Presidência da República, Fundação Instituto Brasileiro de Geografia e Estatística, <u>Anuário Estatístico do Brasil</u>.

<u>GNPPCAP</u>

This variable is derived using the gross national product (GNP) found in Brazil, Secretaria de Planejamento da Presidência da República, Fundação Instituto Brasileiro de Geografia e Estatística, <u>Anuário Estatístico do Brasil</u>, and deflated by the index X. GNPPCAP is defined

TABLE 35

DATA USED IN THIS STUDY--SOME EXOGENOUS VARIABLES

Year	POP	TIME	TIME1	TIME2	TIME3	LABCOST
1958	66,088,358	41	41	0	0	. . .
1959	68,108,018	42	42	0	0	. . .
1960	70,191,370	43	43	0	0	. . .
1961	72,205,160	44	44	0	0	. . .
1962	74,276,726	45	45	0	0	. . .
1963	76,407,726	46	46	0	0	4,419.81
1964	78,599,863	47	47	0	0	4,671.94
1965	80,854,893	48	48	0	0	4,683.77
1966	83,174,620	49	49	0	0	4,337.91
1967	85,560,900	50	50	0	0	4,289.17
1968	88,015,642	51	51	0	0	4,253.13
1969	90,540,811	52	52	0	0	4,257.78
1970	93,139,037	53	53	0	0	4,288.39
1971	95,454,473	54	54	0	0	4,247.36
1972	97,827,472	55	55	0	0	4,313.64
1973	100,259,463	56	56	0	0	4,374.23
1974	102,751,913	57	56	1	0	4,044.79
1975	105,306,325	58	56	2	0	4,284.43
1976	107,924,241	59	56	3	0	4,377.99
1977	110,607,237	60	56	4	0	4,486.13
1978	113,356,933	61	56	4	1	4,579.45
1979	116,174,987	62	56	4	2	4,483.72
1980	119,061,470	63	56	4	3	3,039.60
1981	122,014,195	64	56	4	4	. . .

Year	GNPPCAP	EXCHRATE
1958	0.027562	0.13358
1959	0.031068	0.16533
1960	0.030440	0.19377
1961	0.031048	0.28863
1962	0.032615	0.40688
1963	0.032661	0.58400
1964	0.033823	1.510
1965	0.034032	1.943
1966	0.034265	2.220
1967	0.034918	2.559
1968	0.038735	3.183
1969	0.042133	4.026
1970	0.053767	4.494
1971	0.057366	5.304
1972	0.062373	5.960
1973	0.072398	6.128
1974	0.079055	6.843
1975	0.084228	8.127
1976	0.090322	10.673
1977	0.093140	14.144
1978	0.097749	18.070
1979	0.101213	26.945
1980	0.102031	52.714
1981	. . .	93.125

as:

$$GNPPCAP = GNP/POP$$

EXCHRATE

This variable is the free exchange rate in cruzeiros per dollar found in International Monetary Fund, International Financial Statistics.

APPENDIX C.

SIMULATION RESULTS

TABLE 36

SIMULATION RESULTS FOR THE PER CAPITA DEMAND FOR SUGAR (DCSPCAP)

	OLS (n=12)	3SLS/4	3SLS/7
Statistics of Fit:			
RMSE	0.00053	0.00035	0.00031
RMSPE	0.01342	0.00837	0.00785
Theil's Forecast error measures:			
RCMSE	0.00018	0.00007	0.00006
UM	0.12	0.00	0.00
UR	0.05	0.23	0.05
UD	0.83	0.77	0.95
U1	0.3248	0.2045	0.1891

TABLE 37

SIMULATION RESULTS FOR THE QUANTITY SUPPLIED OF SUGAR (PRODSUG)

	OLS (n=12)	3SLS/4	3SLS/7
Statistics of Fit:			
RMSE	453,930	519,477	443,521
RMSPE	0.06765	0.07422	0.06724
Theil's Forecast error measures:			
RCMSE	0.00524	0.00625	0.00509
UM	0.01	0.00	0.00
UR	0.04	0.02	0.07
UD	0.95	0.98	0.93
U1	0.0000	0.0000	0.0000

TABLE 38

SIMULATION RESULTS FOR THE QUANTITY OF HYDROUS ETHANOL SUPPLIED (PROET185)

	OLS (n=12)	3SLS/4	3SLS/7
Statistics of Fit:			
RMSE	66,716	75,548	65,422
RMSPE	0.19568	0.19199	0.18654
Theil's Forecast error measures:			
RCMSE	0.03288	0.03816	0.03107
UM	0.01	0.00	0.00
UR	0.00	0.05	0.01
UD	0.99	0.95	0.99
U1	0.0000	0.0000	0.0000

TABLE 39

SIMULATION RESULTS FOR THE COST OF HYDROUS ETHANOL (COSTE185)

	OLS (n=12)	3SLS/4	3SLS/7
Statistics of Fit:			
RMSE	1.04380	1.00219	0.98479
RMSPE	0.06208	0.05915	0.05639
Theil's Forecast error measures:			
RCMSE	0.00339	0.00300	0.00276
UM	0.09	0.00	0.00
UR	0.77	0.84	0.81
UD	0.14	0.16	0.19
U1	0.0033	0.0031	0.0030

TABLE 40

SIMULATION RESULTS FOR THE QUANTITY SUPPLIED OF ANHYDROUS ETHANOL (PROET200)

	OLS (n=12)	3SLS/4	3SLS/7
Statistics of Fit:			
RMSE	181,057	180,572	181,731
RMSPE	0.18659	0.18999	0.19916
Theil's Forecast error measures:			
RCMSE	0.09991	0.12699	0.11936
UM	0.02	0.01	0.02
UR	0.15	0.06	0.09
UD	0.83	0.94	0.89
U1	0.0000	0.0000	0.0000

TABLE 41

SIMULATION RESULTS FOR THE QUANTITY SUPPLIED OF SUGAR CANE (PRODCANE)

	OLS (n=12)	3SLS/4	3SLS/7
Statistics of Fit:			
RMSE	4,337,874	5,483,834	4,886,215
RMSPE	0.04637	0.05542	0.05186
Theil's Forecast error measures:			
RCMSE	0.00255	0.00377	0.00320
UM	0.12	0.45	0.20
UR	0.10	0.01	0.13
UD	0.77	0.54	0.67
U1	0.0000	0.0000	0.0000

TABLE 42
SIMULATION RESULTS FOR THE CONSUMPTION OF GASOHOL PER VEHICLE (CGASAVEH)

	OLS (n=12)	3SLS/4	3SLS/7
Statistics of Fit:			
RMSE	0.02038	0.02122	0.01977
RMSPE	0.00792	0.00833	0.00771
Theil's Forecast error measures:			
RCMSE	0.00006	0.00006	0.00006
UM	0.00	0.00	0.00
UR	0.02	0.08	0.03
UD	0.97	0.92	0.97
U1	0.0027	0.0028	0.0026

TABLE 43

SIMULATION RESULTS FOR THE CHANGE IN THE STOCKS OF SUGAR (CHASTSUG)

	OLS (n=12)	3SLS/4	3SLS/7
Statistics of Fit:			
RMSE	470,422	511,070	448,878
RMSPE	3.84334	3.81661	3.09763
Theil's Forecast error measures:			
RCMSE	9.11210	10.11150	10.94640
UM	0.13	0.09	0.15
UR	0.37	0.43	0.42
UD	0.50	0.48	0.43
U1	0.0000	0.0000	0.0000

TABLE 44

SIMULATION RESULTS FOR THE CHANGE IN THE STOCKS OF HYDROUS ETHANOL (CHSTE185)

	OLS (n=12)	3SLS/4	3SLS/7
Statistics of Fit:			
RMSE	66,716	75,548	65,422
RMSPE	1.26775	1.31408	1.51556
Theil's Forecast error measures:			
RCMSE	5.53957	7.83916	6.07302
UM	0.01	0.00	0.00
UR	0.23	0.37	0.32
UD	0.75	0.63	0.68
U1	0.0000	0.0000	0.0000

TABLE 45

SIMULATION RESULTS FOR THE PROFIT MARGIN ON HYDROUS ETHANOL (MARG18)

	OLS (n=12)	3SLS/4	3SLS/7
Statistics of Fit:			
RMSE	1.04380	1.00219	0.98480
RMSPE	0.36774	0.29592	0.29601
Theil's Forecast error measures:			
RCMSE	0.23803	0.16249	0.17198
UM	0.29	0.24	0.22
UR	0.13	0.16	0.19
UD	0.58	0.60	0.59
U1	0.0681	0.0563	0.0579

TABLE 46
SIMULATION RESULTS FOR THE DEMAND FOR ANHYDROUS ETHANOL (GP200)

	OLS (n=12)	3SLS/4	3SLS/7
Statistics of Fit:			
RMSE	59,173	56,548	58,361
RMSPE	0.03021	0.02984	0.02950
Theil's Forecast error measures:			
RCMSE	0.00377	0.00418	0.00347
UM	0.35	0.32	0.32
UR	0.08	0.10	0.04
UD	0.56	0.58	0.64
U1	0.0000	0.0000	0.0000

TABLE 47

SIMULATION RESULTS FOR THE CHANGE IN STOCKS OF ANHYDROUS ETHANOL (CHSTE200)

	OLS (n=12)	3SLS/4	3SLS/7
Statistics of Fit:			
RMSE	184,642	187,259	189,920
RMSPE	8.23545	9.11468	8.69007
Theil's Forecast error measures:			
RCMSE	11.75470	12.13600	13.99780
UM	0.01	0.04	0.00
UR	0.35	0.04	0.33
UD	0.64	0.93	0.67
U1	0.0000	0.0000	0.0000

TABLE 48

SIMULATION RESULTS FOR THE COST OF ANHYDROUS ETHANOL (COSTE200)

	OLS (n=12)	3SLS/4	3SLS/7
Statistics of Fit:			
RMSE	1.09299	1.04941	1.03120
RMSPE	0.06208	0.05915	0.05639
Theil's Forecast error measures:			
RCMSE	0.00339	0.00300	0.00276
UM	0.09	0.00	0.00
UR	0.77	0.84	0.81
UD	0.14	0.16	0.19
U1	0.0031	0.0030	0.0028

TABLE 49

SIMULATION RESULTS FOR THE PROFIT MARGIN ON ANHYDROUS ETHANOL (MARG20)

	OLS (n=12)	3SLS/4	3SLS/7
Statistics of Fit:			
RMSE	1.09299	1.04941	1.03120
RMSPE	18.01220	12.51320	12.96790
Theil's Forecast error measures:			
RCMSE	1,338.760	868.037	918.819
UM	0.17	0.17	0.17
UR	0.03	0.00	0.00
UD	0.80	0.83	0.83
U1	5.1793	4.1705	4.2908

TABLE 50

SIMULATION RESULTS FOR THE CONSUMPTION OF GASOHOL (CGASA)

	OLS (n=12)	3SLS/4	3SLS/7
Statistics of Fit:			
RMSE	463,142	454,847	453,084
RMSPE	0.03021	0.02983	0.02949
Theil's Forecast error measures:			
RCMSE	0.00095	0.00092	0.00090
UM	0.37	0.36	0.37
UR	0.01	0.03	0.01
UD	0.61	0.61	0.62
U1	0.0000	0.0000	0.0000

TABLE 51
SIMULATION RESULTS FOR THE DEMAND FOR SUGAR CANE (CRSCANE)

	OLS (n=12)	3SLS/4	3SLS/7
Statistics of Fit:			
RMSE	5,122,187	5,909,852	4,980,637
RMSPE	0.06192	0.06539	0.06122
Theil's Forecast error measures:			
RCMSE	0.00476	0.00515	0.00452
UM	0.00	0.00	0.01
UR	0.37	0.13	0.28
UD	0.63	0.87	0.71
U1	0.0000	0.0000	0.0000

TABLE 52

SIMULATION RESULTS FOR THE QUANTITY OF OTHER SUGAR CANE (OTHCANE)

	OLS (n=12)	3SLS/4	3SLS/7
Statistics of Fit:			
RMSE	4,771,397	6,264,338	5,414,934
RMSPE	0.24476	0.29762	0.26496
Theil's Forecast error measures:			
RCMSE	0.06351	0.10181	0.08067
UM	0.04	0.31	0.10
UR	0.47	0.23	0.45
UD	0.49	0.45	0.45
U1	0.0000	0.0000	0.0000

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